SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

MF for Solids Determinations—Engelbrecht and McKinney

Lagooning Experiments—Neel and Hopkins

Disposal of Wastes at Sea—Eberman

Plating Wastes and Sewage Treatment—Tarvin

Blast Furnace Flue Gas Treatment—Weise

Operator Training

NOVEMBER 1956—VOL. 28, No. 11

Notice to all Active Members of Member Associations

Your prompt payment of 1957 dues will avoid interruption in receipt of SEWAGE AND INDUSTRIAL WASTES as well as other Federation services. Undue delay may make it impossible for a complete volume of the JOURNAL to be furnished.

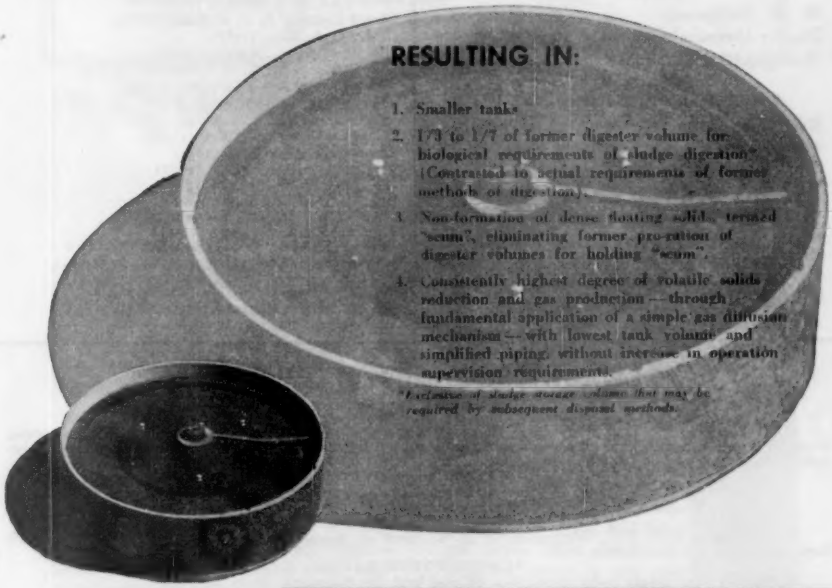
Please remit directly to your Member Association Secretary immediately upon receipt of the first dues notice from him.

CRP*

CATALYTIC
REDUCTION
PROCESS

PERMITS SMALLER TANKS . . .

through exclusively highest solids loading for sludge digestion



RESULTING IN:

1. Smaller tanks
2. 1/3 to 1/7 of former digester volume for biological requirements of sludge digestion* (Contrasted to actual requirements of former methods of digestion)
3. Non-formation of dense floating solids, termed "scum", eliminating former proportion of digester volumes for holding "scum".
4. Consistently highest degree of volatile solids reduction and gas production — through fundamental application of a simple gas diffusion mechanism — with lowest tank volume and simplified piping, without increase in operation supervision requirements.

*Exclusive of sludge storage volume that may be required by subsequent disposal methods.

Reports Available

Reports describing the PROCESS in detail are available on request.
Write to Department F.

* Patents Applied For

fmc

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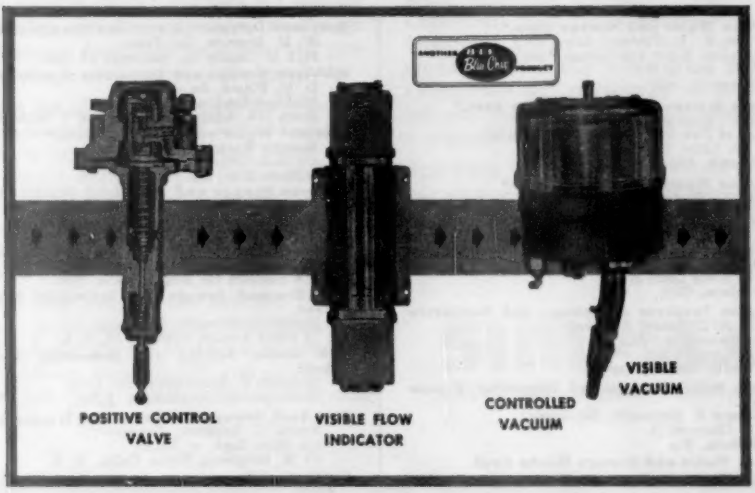

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To get top plant performance, the complex instrumentation—both old and new—would have to be pulled together. Twenty year old meters would have to be modified, rebuilt, or replaced to work alongside today's improved models, telemetering total influent for the entire expanded plant to *one central control point.*

Here's why Simplex was selected to solve these problems. Simplex redesigned and will rebuild the *old* venturi tube receivers to perform dependably and accurately alongside the newest venturi tubes and meters—specially engineered by Simplex to Columbus' exact requirements. From this integrated system of old and new units spread over a big plant area, Simplex Orthoflow® will *electrically* transmit vital influent data to one central control point —instantly, accurately.

Your Plant. We'll gladly help you in expanding your old plant or planning a new one. Write today outlining your problem. Simplex Valve & Meter Company, Dept. SI-11, 7 East Orange Street, Lancaster, Pa.

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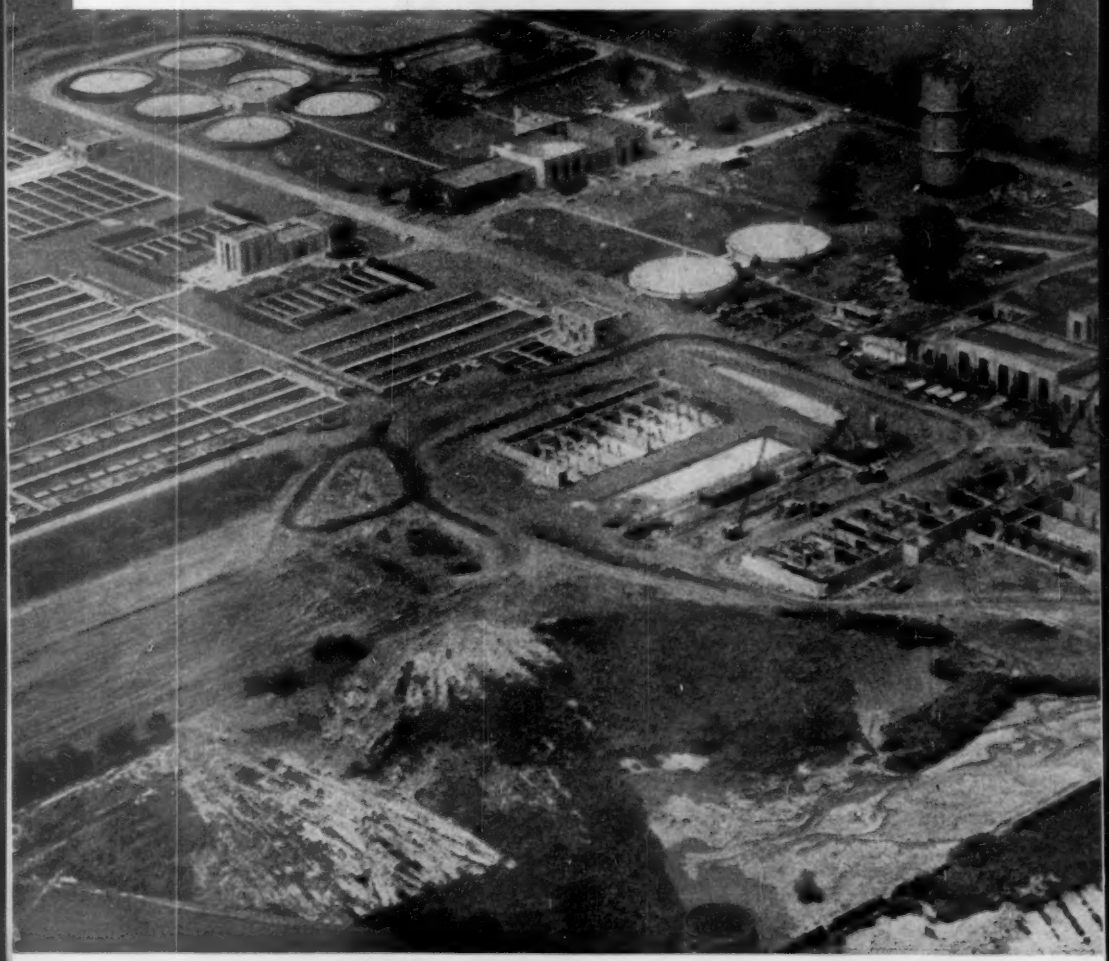


MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Nebraska Sewage and Industrial Wastes Assn.	Castle Hotel Omaha, Neb.	Nov. 1–2, 1956
New England Sewage and Industrial Wastes Assn.	Hotel Weldon Greenfield, Mass.	Nov. 8, 1956
Florida Sewage and Industrial Wastes Assn.	Daytona Plaza Hotel Daytona Beach, Fla.	Nov. 11–14, 1956
North Carolina Sewage and Industrial Waste Assn.	Charlotte Hotel Charlotte, N. C.	Nov. 12–14, 1956
South Carolina Water and Sewage Works Assn.	Jefferson Hotel Columbia, S. C.	Nov. 16, 1956
Rocky Mountain Sewage and Industrial Wastes Assn.	Broadmoor Hotel Colo. Springs, Colo.	Nov. 25, 1956
New York Sewage and Industrial Wastes Assn.	Hotel Belmont-Plaza New York, N. Y.	Jan. 17–18, 1957
Arkansas Water & Sewage Conf.	Marion Hotel Little Rock, Ark.	Mar. 18–20, 1957
Arizona Sewage and Water Works Assn.	Maricopa Inn Mesa, Ariz.	Apr. 4–6, 1957
Kansas Sewage and Industrial Wastes Assn.	Broadview Hotel Wichita, Kans.	Apr. 10–12, 1957
California Sewage and Industrial Wastes Assn.	San Diego, Calif.	Apr. 24–27, 1957
Maryland-Delaware Water and Sewage Assn.	Commander Hotel Ocean City, Md.	May 22–24, 1957

THIRTIETH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
New England Sewage and Industrial Wastes Association
Statler Hotel, Boston, Massachusetts
October 7–10, 1957

Get Faster, More Efficient Sewage Treatment

WITH THE

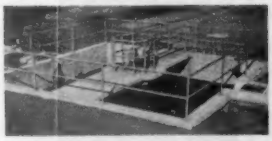
INFILCO *HIGH-RATE* LINE

All INFILCO sewage-treatment equipment is designed for utmost speed and efficiency of operation in the smallest possible space. The line is the most complete in the field, offering units for your every need. Here are a few typical examples. Write today for free literature of interest to you. There is no obligation.

Inquiries are invited also on all other water and waste treating problems, including precipitation, coagulation, sedimentation, filtration, flotation, ion exchange and biological processes.

COMMINUTION

GRIDUCTOR® Comminutors for sewage screening and cutting offer the advantage of straight channel installation plus double-end adjustable cutter teeth which may be resharpened and realigned for longer effective life. **Request Bulletin 5100.**



MIXING

VORTI® Mixers provide rapid turbulent agitation throughout the body of liquid by controlled, multi-directional circulation. They combine the advantages of rapid treatment in minimum space, low power consumption and efficient distribution in a compact unit.

"VORTI" Mixers may be used for continuous or batch agitation in either rectangular or round basins. **Request Bulletin 700.**

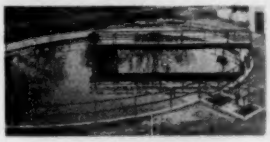
COAGULATION

VORTI-FLOC® Coagulators provide gentle but thorough agitation, without short circuiting, to build up floc particles to optimum size, quickly, for effective liquid solid-separation.

"VORTI-FLOC" units are used in round or square basins. Multiple units operate in rectangular basins, in which the impellers may be mounted, vertically or horizontally, upon a single shaft. **Request Bulletin 700-5401.**

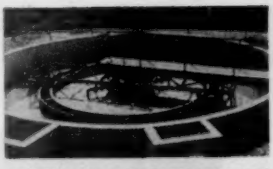
FLOTATION

The **SEDIFLOTOR®** Clarifier is particularly effective in the high-rate treatment of sewage and wastes containing greases, oils, fibers, colloids and light suspended solids. Heavier solids are removed by scrapers. The "SEDI-FLOTOR" unit may be installed in either circular or rectangular basins. **Request Bulletin 6051.**



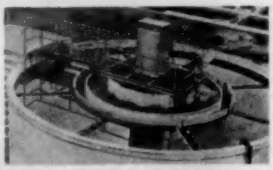
SEDIMENTATION

INFILCO clarifiers provide for the effective removal of suspended solids and surface scum from liquids. The WS Clarifier is suitable for small basins. For large basins, the BF and PDR Clarifiers are recommended. **Request Bulletin 800/5,000.**



MIXING AND SEDIMENTATION

The **CYCLATOR®** Clarifier Type AR has special applications in the treatment of domestic sewage by biological oxidation. The basin has a central compartment containing COLAFLEX® diffusers, in which the sewage is mixed, aerated and coagulated. **Request information.**



ACTIVATED SLUDGE TREATMENT

The **AERO-ACCELATOR** (Trade Mark) activated sludge plant is high-rate process equipment based upon established principles of hydraulics and biochemistry. It provides a compact, highly efficient multi-purpose plant which combines rapid and continuous biological action and clarification, efficient operation at high loadings, stability under shock conditions, and great economy of space. **Request Bulletin 6510.**

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INFILCO Floating Covers are offered in both scum submergence and gas holder types, with necessary auxiliary equipment. **Request Bulletin 6700.**

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History is written on water

Great civilizations of the past — Egypt, Persia, Babylonia — waned when their water sources dwindled.

It could happen to us . . . if we let it.

Today, for example, America's thirst for water is beginning to outrun its supply. Industry and homes use more and more water . . . billions of gallons daily.

Yet average annual rainfall does not increase. And erosion of moisture-holding soil continues. What can *you* do?

Several things: encourage your water officials to plan in advance for necessary water facilities. Support realistic water rates and bond issues designed to increase your supply. And conserve where you can.

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SERVES THE CENTURIES

America's population, productive capacity and national prosperity keep growing.

In more than 64 American cities this upward economic trend is encouraged by an adequate water supply and the cast iron water mains that have carried it so efficiently for a century or more.

Cast iron's longevity and reliability mean continuing, economical service . . . tax dollars saved that can be used to improve service still further.

Rely on Cast Iron Pipe to carry America's Water

Sacramento, Cal. installed this cast iron water main over 100 years ago. It is still doing the job. Yet today's cast iron pipe, modernized and centrifugally cast, is even stronger, more durable.

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Providence Gas Company laid this cast iron gas main more than 100 years ago. It's still serving.

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The Q-Check stencilled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

*Page ads in 4 national newsweeklies and business publications with 9 million combined readership.

pipe FOR MODERN WATER WORKS

A School? No!

*This plant was designed by Henry W. Taylor, Freeport, N. Y

It's an

INCINERATION PLANT

serving Hempstead, N. Y.

- Large but not an eye-sore
- Efficient and flexible

Serving some 450,000 people, this plant provides an excellent example of the way larger communities are handling their refuse problems. Land-filling can no longer be tolerated in the suburban areas and should not be tolerated *anywhere*. Yet, there's no need to have an incinerator plant that's offensive to the nose and eye. Modern design and modern operation take care of the nuisance factors.

For this Hempstead plant, we furnished four Morse Boulger Mechanically Stoked Furnaces for handling up to 700 tons of refuse per 24 hours. Waste heat boilers recover much of the heat and provide steam for two 1000 kw. turbo-generators. Our engineers also furnished the crane charging equipment, stacks, fly ash removal unit and ash removal conveyor.

What we did to help in this Hempstead project we can do to help you...working with your sanitation engineer or your consulting engineer. The point to keep in mind is that your community, too, can have clean, efficient, nuisance-free refuse disposal in a modern incineration plant such as this Morse Boulger plant.

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100 years from now...

WE MAY RAISE CHICKENS AS BIG AS OSTRICHES!

How will we live, eat, travel in the future? Even scientists must include some guesswork in their predictions of the marvelous things to come. But one thing seems certain—water and gas will still be carried by the dependable, long-lasting cast iron pipe laid today. Here's proof! More than sixty American cities are still being served by cast iron water and gas mains over a century old. And today's modernized U. S. Pipe...centrifugally cast, quality controlled . . . is even stronger, tougher, and more durable.

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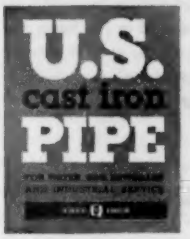
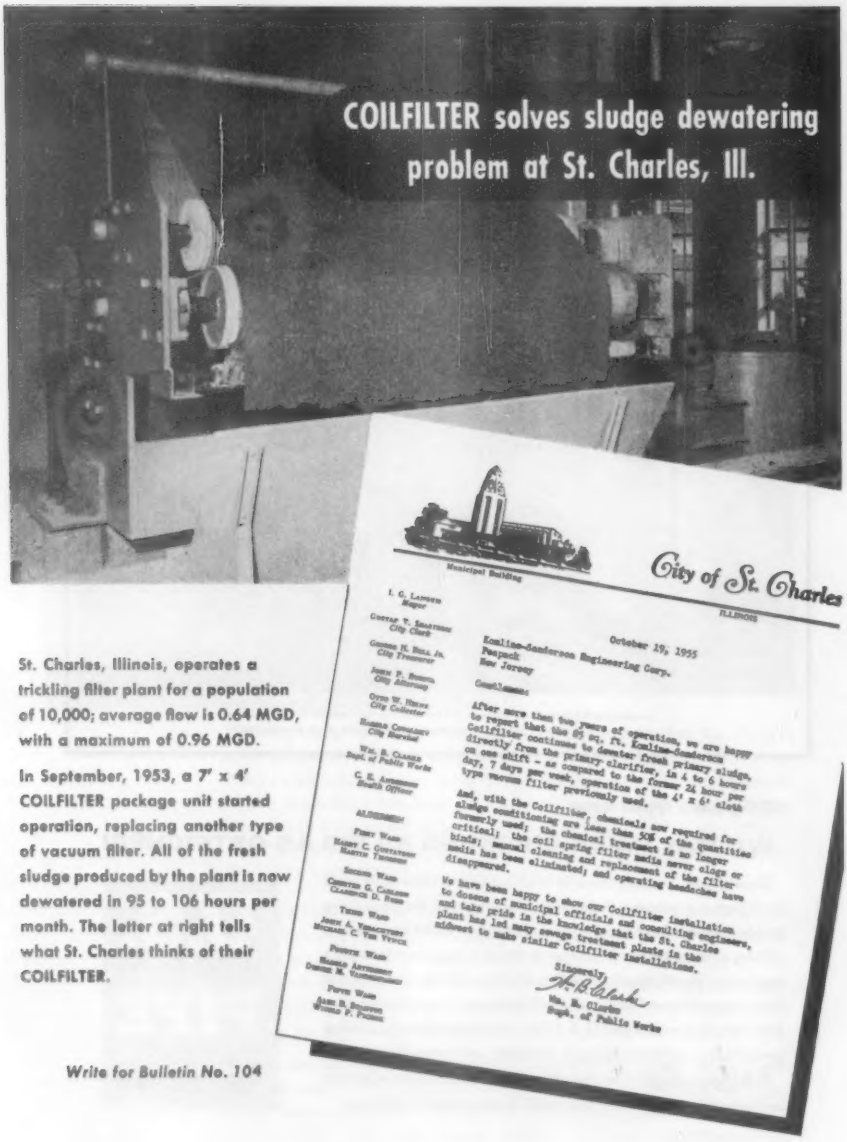


U. S. PIPE AND FOUNDRY COMPANY, General Office: Birmingham 2, Alabama

A WHOLLY INTEGRATED PRODUCER FROM MINES AND BLAST FURNACES TO FINISHED PIPE.


COILFILTER solves sludge dewatering problem at St. Charles, Ill.
Municipal Building
City of St. Charles
ILLINOIS
October 19, 1955
Komline-Sanderson Engineering Corp.
Peapack
New Jersey
Gentlemen:
After more than two years of operation, we are happy to report that the 85 sq. ft. Komline-Sanderson Coilfilter continues to dewater fresh primary sludge, directly from the primary clarifier, in 4 to 6 hours on one shift - as compared to the former 24 hour per day, 7 days per week, operation of the 4' x 6' cloth type vacuum filter previously used.
And, with the Coilfilter, chemicals now required for sludge conditioning are less than 50% of the quantities formerly used; the chemical treatment is no longer critical; the coil spring filter media never clogs or binds; manual cleaning and replacement of the filter media has been eliminated; and operating headaches have disappeared.
We have been happy to show our Coilfilter installation to dozens of municipal officials and consulting engineers, and take pride in the knowledge that the St. Charles plant has led many sewage treatment plants in the Midwest to make similar Coilfilter installations.
Sincerely
Wm. B. Clarke
Supt. of Public Works

St. Charles, Illinois, operates a trickling filter plant for a population of 10,000; average flow is 0.64 MGD, with a maximum of 0.96 MGD.

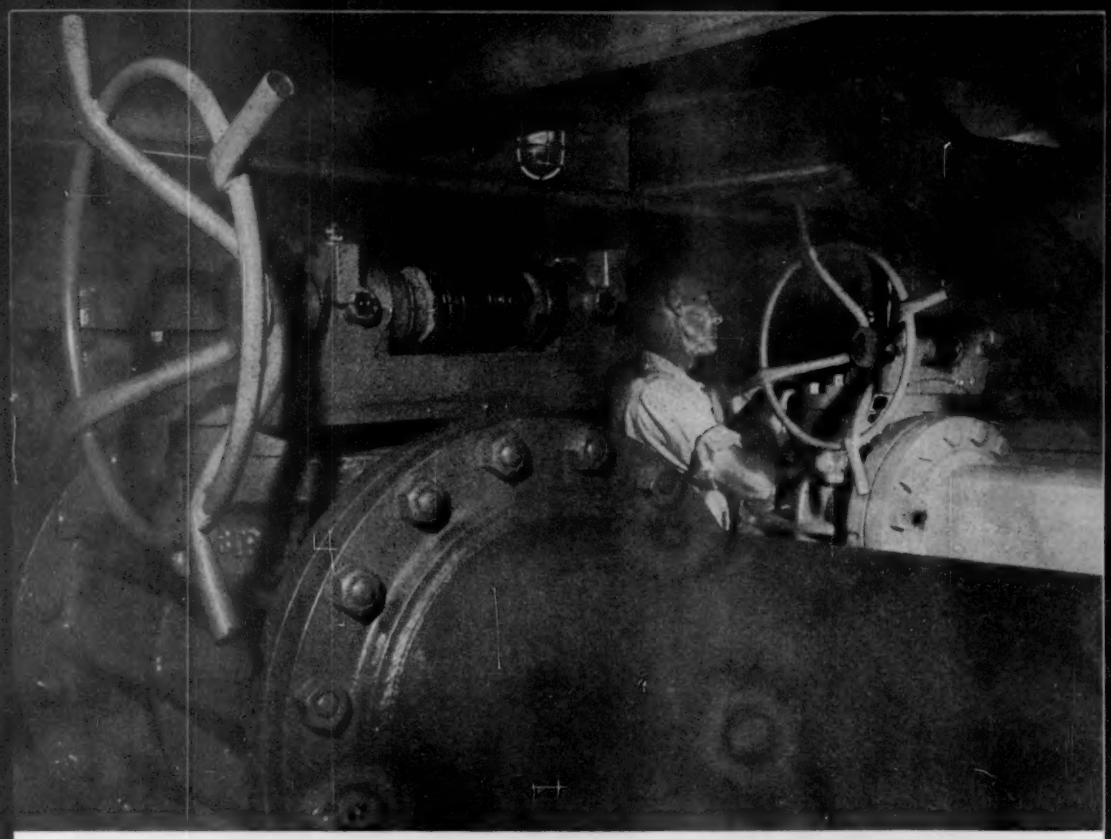
In September, 1953, a 7' x 4' COILFILTER package unit started operation, replacing another type of vacuum filter. All of the fresh sludge produced by the plant is now dewatered in 95 to 106 hours per month. The letter at right tells what St. Charles thinks of their COILFILTER.

Write for Bulletin No. 104

KOMLINE-SANDERSON ENGINEERING CORPORATION

Peapack, New Jersey

MANUFACTURERS OF COILFILTER SLUDGE VACUUM FILTERS



WHY A TAPERED PLUG?

Only a tapered plug *adjusts itself* into the valve body for perfect seating . . . yet is easily freed for operation. In Rockwell-Nordstrom valves, the tapered plug is even more efficient because it is seated on a film of pressurized lubricant. Acting like a spring, lubricant pressure keeps the tapered plug "cushioned" for instant, easy operation. Galled or stuck valves are prevented on even the most difficult waste plant services.

Pressurized lubricant in Rockwell-Nordstrom valves has two more important jobs. It also forms a leakproof seal for positive shut-off on heaviest sludge or light gases. And by eliminating the wear of metal-to-metal abrasion, lubrication saves maintenance and repair costs.

Rockwell-Nordstrom valves come in sizes to 16" and WOG ratings to 200 lb. for every waste plant need. They save money, improve performance everywhere you use them, yet Rockwell-Nordstrom valves cost no more than ordinary valves. Send the coupon for complete information. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

Canadian Valve Licensee: Peacock Brothers Limited

ROCKWELL-
Nordstrom
VALVES

Lubricant Sealed For Positive Shut-Off

40th YEAR *of lubricated plug valve leadership*

SEND THE COUPON FOR FREE BOOKLET

Rockwell Manufacturing Company
Pittsburgh 8, Pennsylvania

☐ Please send me Bulletin C-5200.

☐ Please have your sales engineer call.

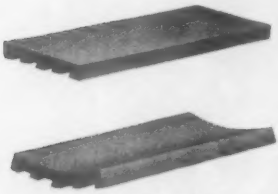
Name_____ Title_____

Address_____

City_____ Zone_____ State_____

Amvit CLAY LINER PLATES *resist abrasion*

provide smoother flow, added protection



Standard size 9" x 24"
Other sizes upon request

● For *complete* protection of concrete pipe sewers, industrial sewers, culverts, acid vats, sewage treatment tanks, neutralizing baths and laboratory and industrial walls and floors choose and use *Amvit* clay liner plates.

They are specially manufactured to meet all application requirements which entail resistance to acids, alkalies and chemical reaction.

Amvit clay liner plates, hardened, glazed, smooth, acid-proof and durable, permanently bond and lock to masonry and concrete work. They install easily to concrete forms and are sized according to standardized specifications for uniform spacing.

For more information, write or call for our detailed booklet on Amvit liner plates. American Vitrified Products Company, National City Bank Building, Cleveland, Ohio, or our office nearest you.

102" reinforced concrete pipe lined with Amvit curved clay liner plates being installed in a combination storm and sanitary sewer.

SINCE 1906

American Vitrified Products Company

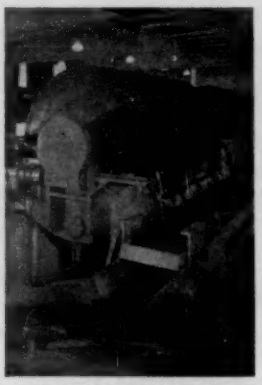
CLEVELAND, OHIO

MANUFACTURERS of: Clay pipe, flue liners, clay liner plates and concrete pipe.

Plants Across the Nation...Brazil, Indiana • Chicago, Illinois • Cleveland, Ohio • Crawfordsville, Indiana • Detroit, Michigan • East Liverpool, Ohio Fenton, Michigan • Grand Ledge, Michigan • Lisbon, Ohio • Los Angeles, California • Milwaukee, Wisconsin • South Bend, Indiana • Uhrichsville, Ohio

PRE-AERATION increases efficiency of 20 tanks equipped with sludge collectors. Air floats grease, flocculates solids and adds dissolved oxygen to the effluent.

FOUR LINK-BELT grit collectors slow sewage velocity to 1.25 fps . . . and remove grit from lighter solids that remain in suspension.



SLUDGE CAKE is conveyed from vacuum filters by Link-Belt belt conveyors. It is used as "Soil Conditioner" by the City Park, nurseries and home gardeners.

How Sacramento effectively controls ODOR - - POLLUTION - - DISPOSAL

LINK-BELT pre-aeration and sludge removal equipment satisfies rigid water purity standards

SINCE 1949, Sacramento's population and industry have increased 50%. To stop odors and water pollution in the Sacramento River, the city recently installed a new sewage treatment plant equipped with Link-Belt grit collecting and washing equipment, sludge collectors and skimming equipment, and belt conveyors for handling the dewatered sludge. The equipment was included in specifications drawn up by the engineering office of Clyde C. Kennedy, Consulting Engineers.

Link-Belt's complete line of equipment and broad engineering experience provide low-cost, efficient water, sewage and waste treatment for municipalities and industries throughout the country. A call to your nearest Link-Belt office will put you in touch with our sanitary engineers who will work with your consultants and chemists.

14,230

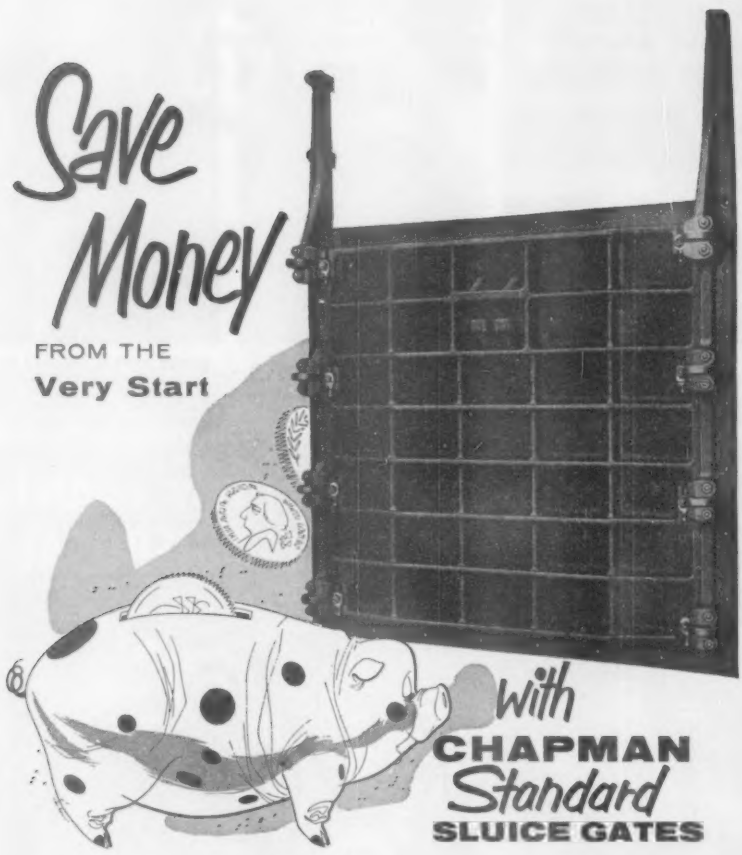
LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.

Save Money

FROM THE
Very Start



with
CHAPMAN
Standard
SLUICE GATES

At the very beginning, Chapman Standard Sluice Gates save you money. In fact, they save money even before they're used.

In more than 300 types and sizes available, all component parts are standardized... *interchangeable.* You eliminate hit or miss installations. You get a sluice gate that meets *your* specifications. Fits perfectly at the lowest cost, because expensive and time consuming matchmaking and field alterations are eliminated.

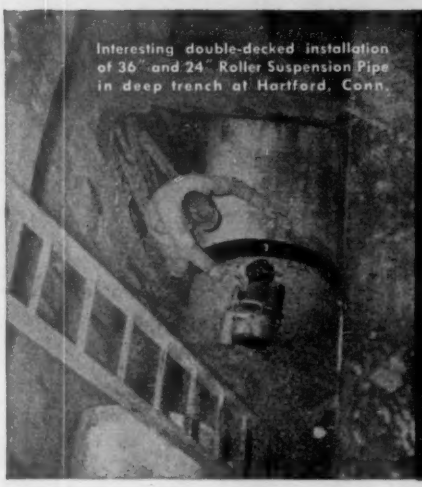
When installed, Chapman Standard Sluice Gates continue to save money. The standardized parts are easy to replace . . . easy to fit . . . without expensive repair or service.

For any requirement . . . high or low head, seating or unseating pressures, large or small water areas . . . Chapman Standard Sluice Gates will meet your demands both for price and cost. You can have them with manual, hydraulic or electric motor operation.

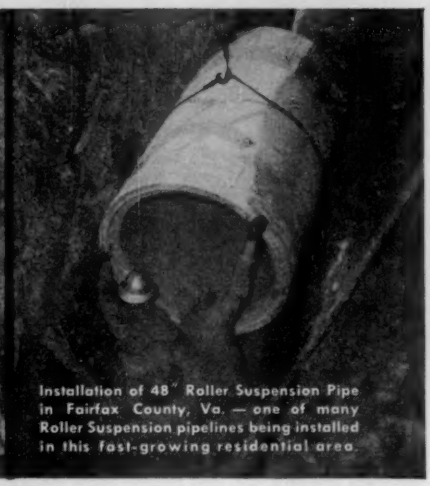
Read all about them in our Catalog 25-A . . . Sent immediately at your request.

THE CHAPMAN VALVE MFG. COMPANY
INDIAN ORCHARD, MASSACHUSETTS

FOR EXCEPTIONAL STRENGTH
LOCK JOINT
ROLLER SUSPENSION PIPE



Interesting double-decked installation of 36" and 24" Roller Suspension Pipe in deep trench at Hartford, Conn.



Installation of 48" Roller Suspension Pipe in Fairfax County, Va. — one of many Roller Suspension pipelines being installed in this fast-growing residential area.

The unique manufacturing process by which Lock Joint Roller Suspension reinforced concrete sewer and culvert pipe is produced permits the use of a low water-cement ratio and a high proportion of stone in the mix. The concrete obtained by this system is unusually strong and resistant to abrasion.

Roller Suspension Pipe of equal wall thickness and steel area to cast or machine made concrete pipe consequently offers a considerable premium in strength and durability.
For projects requiring exceptionally rugged sewer or culvert pipe, specify Lock Joint's ultra-modern ROLLER SUSPENSION PIPE.

LOCK JOINT PIPE CO.
East Orange, N. J.

Sewer and Culvert Pipe Plants:

Kenilworth, New Jersey	Valley Park, Missouri	Cheyenne, Wyoming
Hartford, Connecticut	N. Kansas City, Missouri	Casper, Wyoming
New Haven, Connecticut	Tulsa, Oklahoma	Tucumcari, New Mexico
Beloit, Wisconsin	Oklahoma City, Oklahoma	Hato Rey, Puerto Rico
Chicago, Illinois	Wichita, Kansas	Ponce, Puerto Rico
Rock Island, Illinois	Denver, Colorado	Caracas, Venezuela

Also Great Lakes Concrete Pipe Company with plants at Buffalo, N. Y. and Henrietta, N. Y.

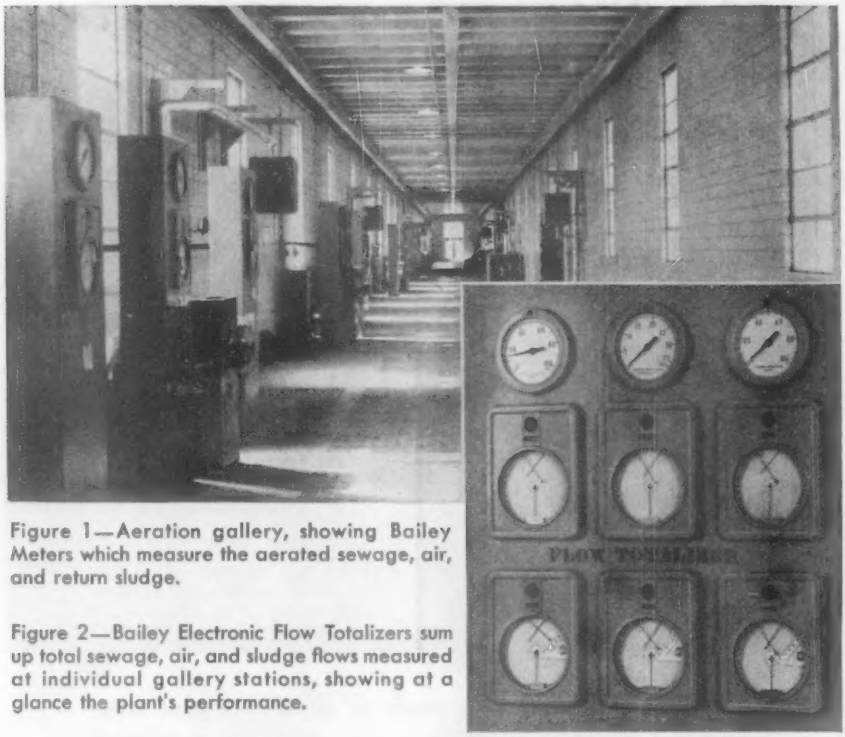


Figure 1—Aeration gallery, showing Bailey Meters which measure the aerated sewage, air, and return sludge.

Figure 2—Bailey Electronic Flow Totalizers sum up total sewage, air, and sludge flows measured at individual gallery stations, showing at a glance the plant's performance.

Havens & Emerson—Consulting Engineers

FLOW TOTALIZATION – at Southerly Sewage Treatment Plant

Instantaneous plant performance and operating trends are continuously available to supervisors and operators through Bailey's Electronic Flow Totalizer.

The new 32 MGD addition to the Southerly Sewage Treatment Plant, Cleveland, Ohio is equipped with Bailey Flow Meters, Integrators, Indicators, and Recorders.

Complete instrumentation and automatic controls for sewage and industrial waste treatment plants are engineered and manufactured by Bailey to meet the most rigid requirements of any size plant.

If you are planning new construction, a Bailey Application Engineer will be pleased to help you lay out your instrument and control requirements. MU-26

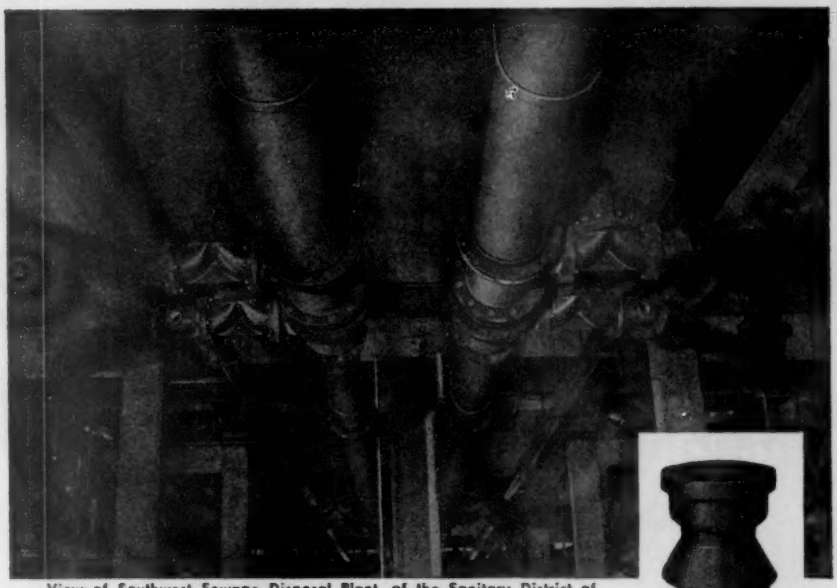
WATER & WASTE TREATMENT DIVISION

BAILEY METER COMPANY

1066 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS



View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . where Clow Cast Iron Pipe was furnished to meet exact requirements.

Clow cast iron pipe, fittings, valves and specials for sewage plant replacements or new installations

● James B. Clow & Sons with their many years of experience as manufacturers of Cast Iron Pipe and Special Castings for Filtration and Sewage Disposal Plants know the difficult piping problems that continually face the sanitary engineer. Clow shops are completely equipped with the latest machinery. Clow's skilled workmen will produce pipe and specials to your exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or with mechanical joint and plain end—in sizes 3 through 24 inches in laying lengths up to 18 feet.

CLOW (Threaded) Cast Iron Pipe

Clow also manufactures (threaded) Cast Iron Pipe in steel pipe sizes 3 through 10 inches which has the same outside diameter as common steel pipe. This pipe can be cut, threaded and fitted on the job with ordinary tools of the piping trade.

JAMES B. CLOW & SONS ☆

201-299 North Talman Avenue • Chicago 80, Illinois

Subsidiaries:
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Oskaloosa, Iowa

sewage treatment plants can be good neighbors, too . .

Can sewage treatment plants be good neighbors? Yes—if the housekeeping is good, and all sewage solids are reduced to ash immediately in Nichols Herreshoff Multiple Hearth furnaces.

As illustrated here, the necessity of building sewage treatment plants adjacent to residential areas is becoming more prevalent. These plants must not offend their neighbors with odors, smoke or fly ash.

Modern Nichols Herreshoff furnaces convert by high temperature combustion all putrescible solids of sewage—grits, grease, screenings and sludge —to clean, innocuous gases and inert ash.

Yes, sewage treatment plants can be good neighbors.

Illustrated here are two views of the West New York, N. J., sewage treatment plant, Nichols Herreshoff equipped.

CONSULTING ENGINEER: Frank J. Olori, West New York, N. J.

Nichols Herreshoff

Multiple Hearth Dryer-Incinerators

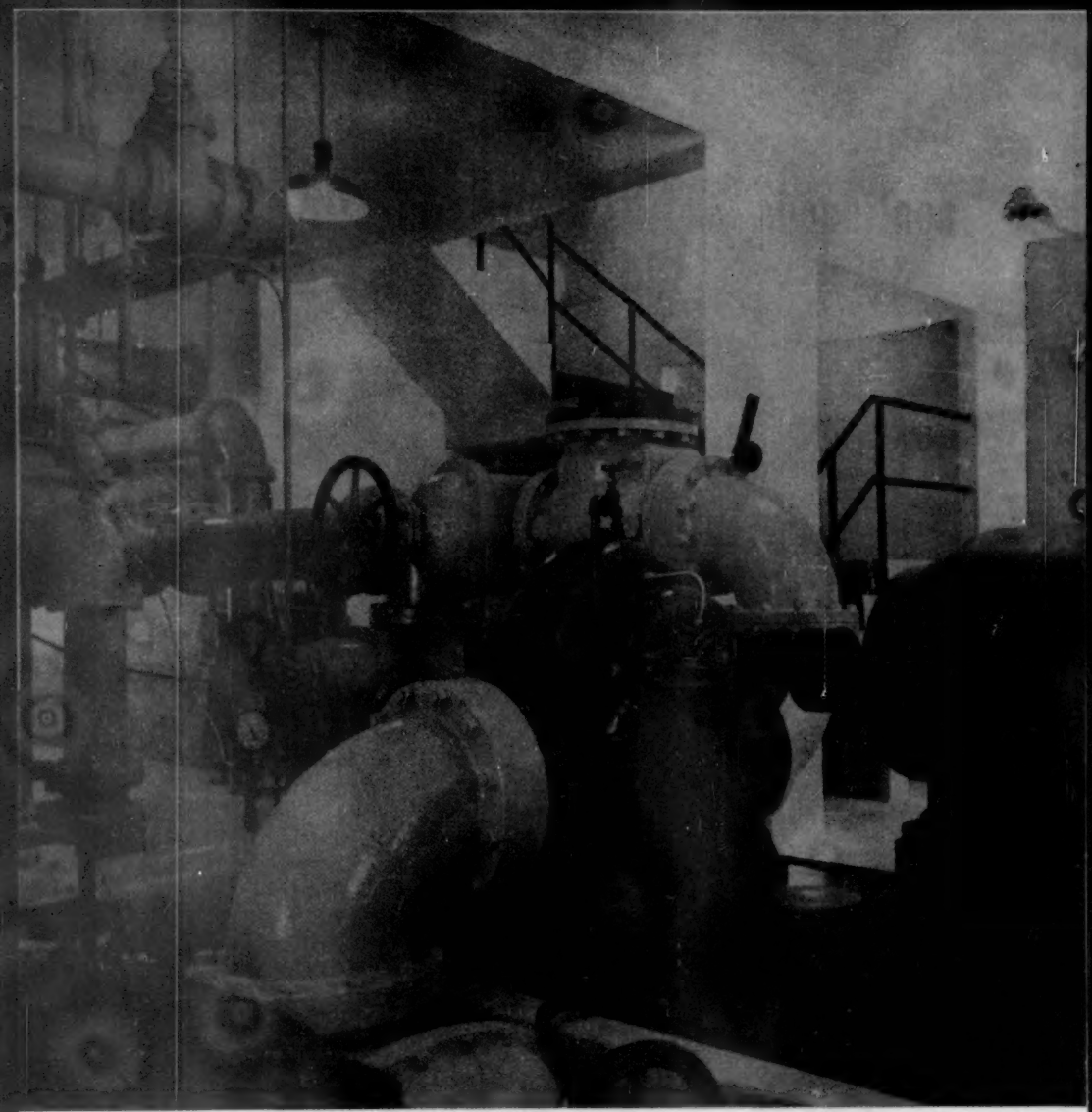
•

Nichols Engineering & Research Corp.

70 PINE ST., NEW YORK 5, N. Y.

1637 N. Illinois St., Indianapolis 2, Ind.

1477 Sherbrooke St. W., Montreal 25, Canada



F-M backwash pump in the St. Charles filtration plant. Consulting Engineers: Barnard & Burk, Baton Rouge, La.

Rain barrel retired

A short four years ago, one district of the Louisiana Parish of St. Charles was taking its drinking water from cisterns. Now St. Charles has a million-dollar filtration plant with nine Fairbanks-Morse pumps on duty to serve the 1800 customers so far connected.

In every size community—large or small—there are Fairbanks-Morse pumps on the vital arteries of water supply and sewage disposal.

If your municipal system is straining under the load of a growing population, Fairbanks-Morse will welcome the opportunity to draw on this wealth of experience and work with your consulting engineer to recommend an efficient expansion of your facilities. Fairbanks, Morse & Co., Dept. SIW-11, 600 So. Michigan Ave., Chicago 5, Ill.

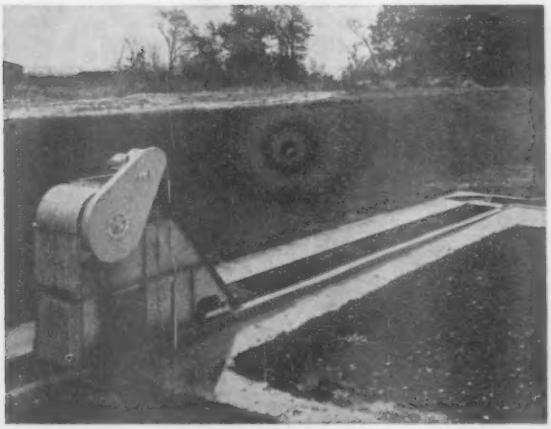
FAIRBANKS-MORSE

a name worth remembering when you want the BEST

PUMPS • SCALES • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY • RAIL CARS
HOME WATER SERVICE EQUIPMENT • MOWERS • MAGNETOS

continuous service / GRIT COLLECTORS and WASHERS

are available in three types to meet every plant condition: **Scraper Type** (shown below); **Elevator Type** for small sewage treatment plants; **V-Bucket Type** where space is limited and grit must be carried to greater heights. Each type is continuous — not only gathers and washes grit but elevates it for discharge into receptacles or for further washing and separation in Jeffrey JIGRIT Washers. JIGRIT Washers remove more than 90% of the putrescible solids. They produce washed grit suitable for use as fill on walkways, roadways, etc. For Catalog 833-A, write to Sanitation Sales Division, The Jeffrey Manufacturing Company, Columbus 16, Ohio.



Apron, Belt, Spiral Conveyors
Bar and Disc Type Screens
Biofiltration Plant Equipment
Bucket Elevators
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Dry Chemical Feeders
FLOCTROLS
Garbage Grinders
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CONVEYING • PROCESSING • MINING EQUIPMENT
TRANSMISSION MACHINERY • CONTRACT MANUFACTURING

The Chicago Sewage Disposal System

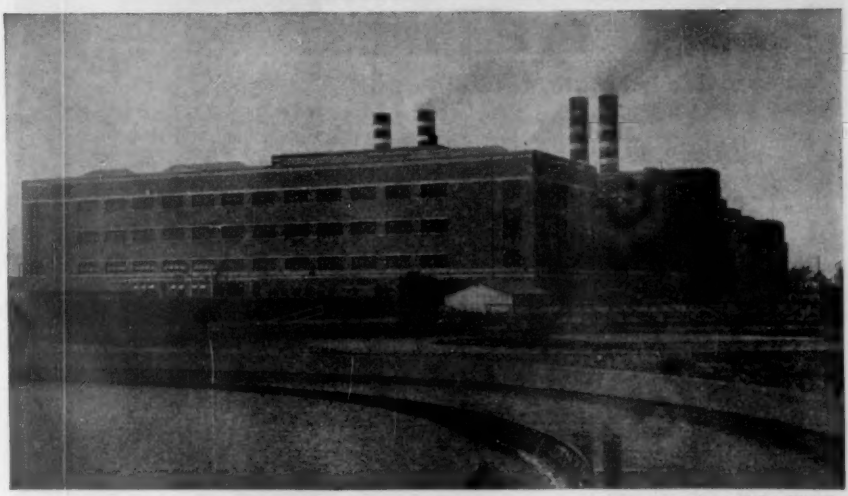


Photo courtesy CIVIL ENGINEERING

One of the 7 Civil Engineering Wonders of the United States

That's the expert opinion of the American Society of Civil Engineers. It happened October 20th, 1955, when the A.S.C.E. selected the country's seven modern wonders of civil engineering. (The other six: Colorado River Aqueduct... Empire State Building... Grand Coulee Dam... Hoover Dam... Panama Canal... San Francisco-Oakland Bay Bridge).

There's good reason why the Metropolitan Sanitary District of Greater Chicago should be so highly honored. For its Sewage Disposal System, constructed at a cost of many millions of dollars, is the largest of its kind anywhere in the world. And its construction involved exceptional achievements—such as the reversal of flow of the Chicago River, to prevent pollution of Lake Michigan, which is Chicago's fresh water source.

Some idea of the size of the facilities owned and operated by the Chicago Sanitary District may be gained from these figures: the system treats and disposes of the sewage from a population of 4,500,000 people . . . handles Chicago's industrial wastes, which add a population equivalent of 3,000,000 more. Its plants treat more than a billion gallons of sewage a day, and discharge a clear, safe effluent.

For twenty years, Combustion Engineering, and its Raymond Division, have served the Sanitary District of Chicago. Seventeen C-E Raymond Flash Drying Systems dry or incinerate the vast quantities of filter cake produced daily, and seven C-E Pulverized Fuel-Fired Boilers provide for steam requirements. C-E is proud of this long, continuous association with Chicago's Sewage Disposal System, and extends hearty congratulations for the recognition accorded it by the American Society of Civil Engineers.

COMBUSTION ENGINEERING C-E B-899A

RAYMOND DIVISION

1315 North Branch Street, Chicago 22, Illinois

Eastern Office: 200 Madison Avenue, N. Y. 16, N. Y. *Western Office:* 510 West Sixth Street, Los Angeles 14, Calif.
Canada: Combustion Engineering-Superheater Ltd.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

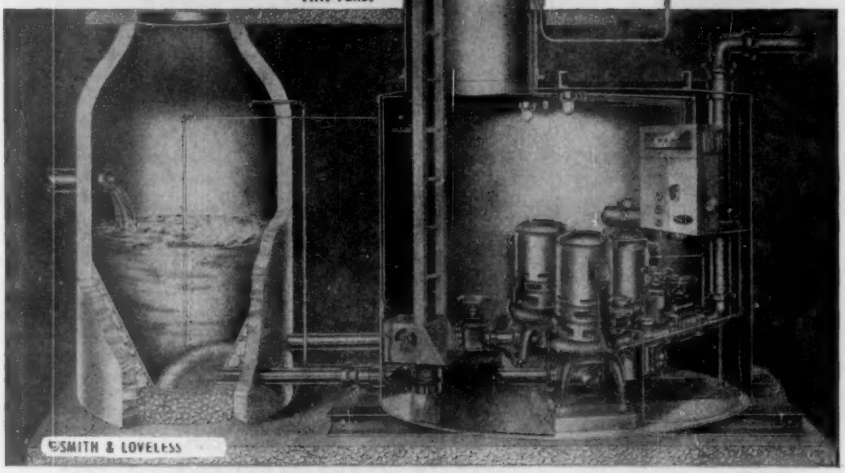
CONCRETE PIPE
provides strength, durability and economy for:
WATER LINES. Concrete pipe's great structural strength, tight joints and uniformly dense structure prevent leakage. There is no tuberculation and less incrustation to impair hydraulic efficiency. Concrete pipe minimizes taste, odor and dirty water difficulties and is not effected by electrolysis.
SEWERS. Concrete pipe sewers have served for more than 100 years. They have the durability to render years of economical service, the strength to sustain heavy overburdens. Their smooth interior finish resists abrasion, assures maximum carrying capacity.
CULVERTS. Concrete pipe provides real economy in culverts. It is a good investment because of its moderate first cost and exceptionally long life. Concrete pipe culverts have been proved by long service under thousands of miles of federal, state and county highways and roadbeds of many leading railroads.
PORTLAND CEMENT ASSOCIATION
33 West Grand Avenue, Chicago 10, Illinois
A national organization to improve and extend the uses of portland cement and concrete . . . through scientific research and engineering field work

HUNDREDS OF INSTALLATIONS—IN 27 STATES!

Smith & Loveless FACTORY-BUILT PUMPING STATION

PROVEN QUALITY— WITH FACTORY-BUILT SAVINGS

PAT. PEND.



We specialize in building America's finest sewage lift stations. Acceptance proves their quality. Smith & Loveless offer you a complete line of six standard size lift stations with capacities from 20 GPM to 1600 GPM per pump or ejector. Larger capacity stations are built to your order.

- An integrated design, each piece proven by the test of time.
- Precision assembled by factory experts.
- Automatic dehumidifier to eliminate condensation.
- A central electrical control cabinet prewired and color coded.
- Shot blasted steel structure epoxy coated plus cathodic protection.
- Factory tested and adjusted by actual operation before shipment.
- Easily and quickly installed.
- Especially designed for minimum maintenance.

For Job Recommendations, complete specifications, and drawings — all part of the latest edition of the 100 page Smith & Loveless lift station Data Manual . . .

WRITE DEPARTMENT 30

S&L

Smith & Loveless, Inc.

P. O. BOX 8172 KANSAS CITY, MISSOURI

Manufacturing Plant • Merriam, Kansas

REPRESENTATIVES IN PRINCIPAL CITIES

The time has come . . . to speak of many things ABOUT CHLORINATORS

You needn't be confused, Alice . . . you are in a modern chlorinator wonderland. Although two chlorinators may look the same, one is but a looking-glass reflection of the real one. The F&P Chlorinator, Alice, is the *real* one, so superior in engineering design and construction, accepted and proven in thousands of installations that others must *try* to imitate it.

There are many things, Alice, that are found only in the F&P Chlorinator. For instance, the F&P Chlorinator is the *only* chlorinator with a single stack controller, the result of a constant program of improvement. Materials that appeared sound 4 years ago have been discarded by F&P and replaced with better materials. Imitations do not benefit from this experience. Only F&P has the experience to supply you with a proven, instrument type, completely corrosion-resistant chlorinator. Don't buy an *untried* Chlorinator.

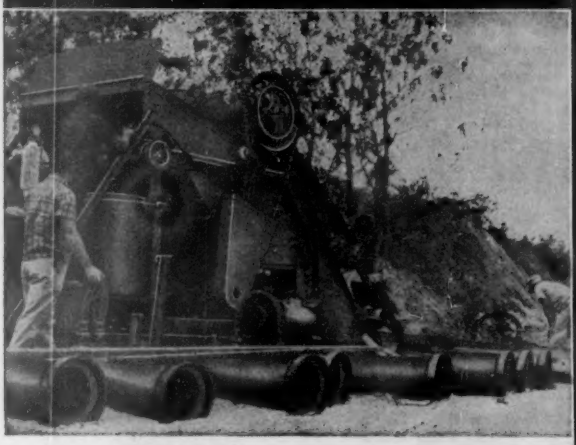
Other things, too, Alice . . . things called intangibles, can't be copied. Such things as dependability, simplicity and experience. So you see—things can "look alike" and not be at all.

If *you're* confused about chlorinators there's one sure way to sweep away *all* confusion. Ask for a free trial of the F&P Chlorinator. Put it to any test you can devise, try it until you're convinced the F&P Chlorinator is far and away better than any other chlorinator ever devised, works better, costs less at the outset and less to maintain. You can't beat it. Write today for complete information and absolute money back guarantee.

FP FISCHER & PORTER

1216 Fischer Road, Hatboro, Pa. LA1119B

When it's bond-financed . . . don't take chances!



Specify NEVER-WEAR-OUT CLAY PIPE

SANFORD, FLORIDA, chose Vitrified Clay Pipe for this bond-financed project, where 22 miles of sanitary sewer lines are being installed. Clay Pipe is being used *exclusively*, because it's the one material that's sure to be good as new long after the bond issue has been retired. Chemically inert Clay Pipe is *permanently* safe against corrosion from the acids and gases found in every form of sewage—residential or industrial. It stays true to dimensions—hot or cold, wet or dry, year in and year out. And today's longer, stronger Clay Pipe, developed through industry-wide research, is easier to install than ever before. A variety of new jointing methods and materials keep it leak-proof and infiltration-proof. Take advantage of *guaranteed performance* with Clay Pipe.

Officials directing the Sanford project include:

City Manager
Warren E. Knowles,

Consulting and Design Engineers
Robert M. Angas & Associates, and

General Contractors
Bumby & Stimpson, McPoland Brothers, and the Hubbard Construction Co.

Vitrified CLAY PIPE

NATIONAL CLAY PIPE MANUFACTURERS, INC.
1820 N. Street, N.W., Washington 6, D. C.

206 Connally Bldg., Atlanta 3, Ga.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
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Progress in Public Health - Through Clay Pipe Research

C-455-9A

Here's the alum of unvarying quality and uniformity . . . a highly efficient, dependable and economical coagulant for removing turbidity from water, for reducing tastes, odors, colors. Water men, America over, prefer General Chemical Aluminum Sulfate for making water good to drink and crystal clear. Make it your choice, too!

Your Most Dependable Supplier—General Chemical has 25 Aluminum Sulfate plants strategically located across the country. This means a source of supply you can always count on in your daily operations . . . in emergencies. Take advantage of it!

For Water Treatment

- Produces crystal clear water
- Gives better floc formation
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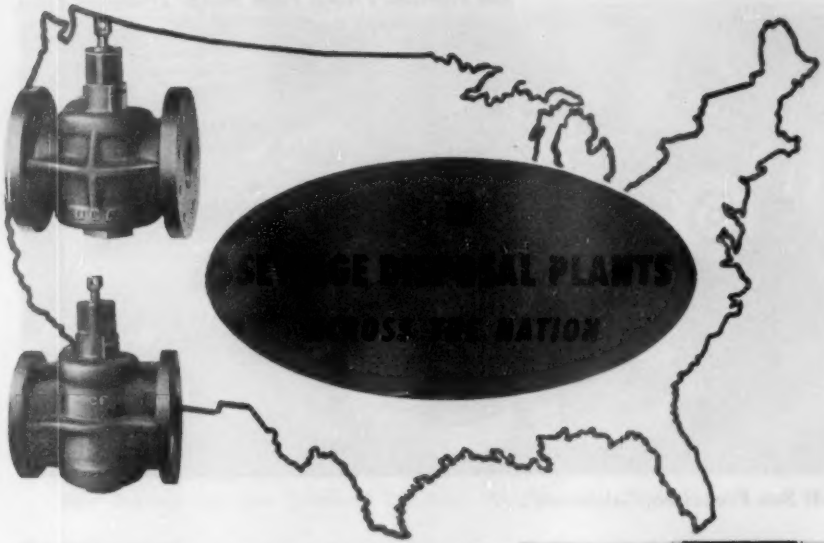

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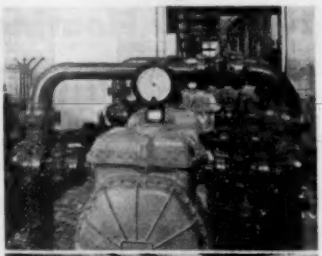

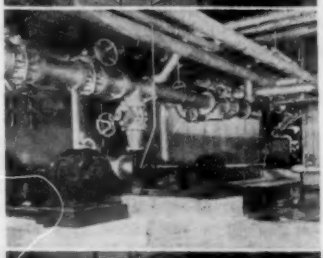

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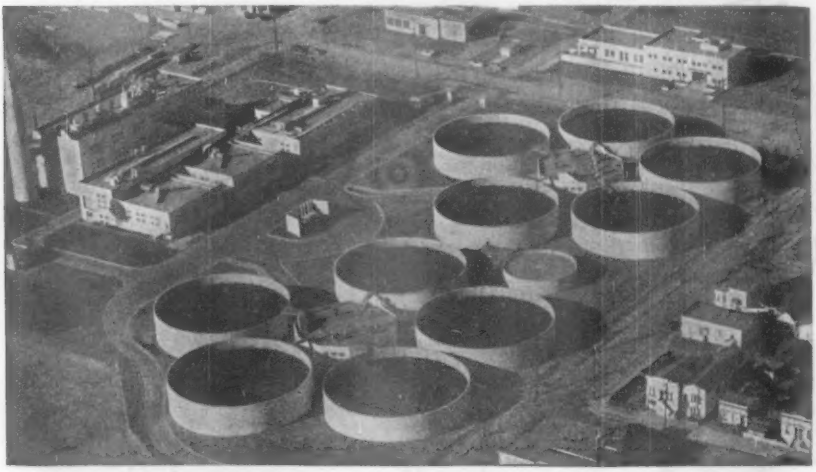

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 28 | November, 1956 | Number 11

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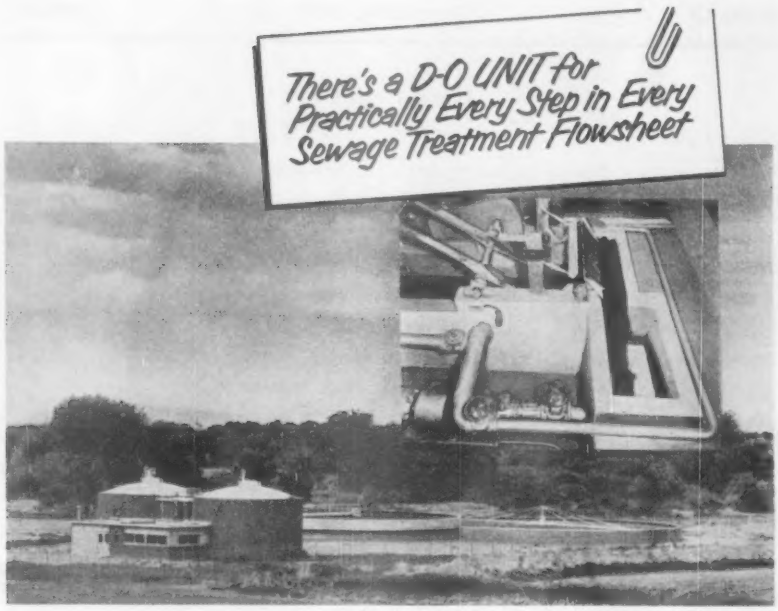

General view of the plant. Inset, closeup of Bar Screen and Disintegrator. Consulting Engineers: Ripple & Howe, Denver, Colorado.

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Sewage Works

MEMBRANE FILTER METHOD APPLIED TO ACTIVATED SLUDGE SUSPENDED SOLIDS DETERMINATIONS

By Richard S. Engelbrecht and Ross E. McKinney

Respectively, Research Assistant Professor of Sanitary Engineering, University of Illinois, Urbana, Ill., and Assistant Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

In undertaking a study of the mass-energy relationship in the activated sludge process, a method for quantitatively and accurately determining aeration solids was necessary. At the present time, the suspended matter or aeration solids present in activated sludge mixed liquors is measured by either the aluminum dish or Gooch crucible methods (1). Both of these methods have definite limitations, especially as applied to this particular research study. The amount of solids removed by these methods depends principally on the kind and degree of fineness of the filter medium. This is reflected in the thickness of the mat in the Gooch crucible and the type of filter paper used with the aluminum dish method. Furthermore, these methods do not quantitatively determine all the organisms present in activated sludge mixed liquors because many of the non-flocculent organisms pass through the filter medium into the filtrate.

The literature in recent years has contained a number of articles (2) (3) (4) concerned with the application of the membrane filter technique to the bacteriological analysis of water and sewage. It has been shown that this filtration method effectively removes all organisms, producing a sterile filtrate. This is related to the fact that the membranes as fabricated today have a calculated pore size of 0.4 to 0.45 micron (μ). This means that all particles, including bacteria, larger than 0.5 μ will be quantitatively retained on the membrane. Therefore, in using this method for measuring activated sludge mixed liquor suspended solids, all organisms, both flocculated and free-swimming, are determined. It is the purpose of this paper to describe the procedure and precision associated with the membrane filter method of determining activated sludge mixed liquor suspended solids.

Method

Apparatus

1. Filtration unit *—a seamless funnel fastened to a porous plate for supporting the membrane.

2. Filter membranes—Millipore Filter type HA or its equivalent; 47 mm. in diameter.

3. Filtering flask—one-liter flask with side arm.

4. Suction apparatus—electric vacuum pump or water aspirator.

5. Aluminum dish—lightweight weighing dish 60 mm. in diameter.

* Filter assembly xx1004700, manufactured by the Millipore Filter Corp., Watertown, Mass.

Procedure

Place a single membrane in a lightweight aluminum weighing dish and weigh. Using forceps to handle the membrane, place it on the porous plate and assemble the filtration unit. Measure a suitable size sample, 25 or 50 ml., with a large tip pipette, and filter under suction. Remove the membrane plus solids with forceps and replace it in the aluminum dish and dry at 103° C. for 1 hr.; cool and weigh.

Results

In order to evaluate the membrane filter method for determining suspended solids, activated sludge cultures were produced in the laboratory on settled domestic sewage and on a synthetic sewage. These cultures were developed and fed on a fill-and-draw basis. The concentration of aeration solids was adjusted by wasting various amounts of mixed liquor. From 10 to 25 replicate analyses were made at various solid concentrations to determine the precision of this technique.

The data for various concentrations of mixed liquor suspended solids, analyzed by the membrane filter technique, are shown in Table I. The mean solid concentration for both the settled domestic and synthetic sewage cultures varied from 276 to 4746 mg. per liter, while the standard deviation ranged from ± 7.1 to ± 37.0 mg. per liter. Considering all of the cultures, except system No. 8, the maximum percentage standard deviation was less than 1.6 per cent. System No. 8 showed a standard deviation of 2.8 per cent. This is normal since the sampling error tends to rise quite rapidly with low solid concentrations.

The results of systems Nos. 9 and 10 were obtained with the same solids on the same day. Increasing the sample size from 25 ml. to 50 ml. resulted in a decrease in the standard deviation from ± 16.7 to ± 9.5 mg. per liter. This increase in precision was the direct result of reducing the sampling error. The major problem in determining mixed liquor suspended solids is the sampling error or the obtaining of representative samples.

A comparison was made between the membrane filter and Gooch crucible methods of determining mixed liquor solids. The analyses were made simultaneously using the same activated sludge culture. The results are shown in Table II. While the mean solid concentration values of the two methods do not differ significantly, the standard deviations show that more consistent results are produced with the membrane filter method. Furthermore, assuming the weighing time in both methods to be the same, the Gooch crucible method required approximately twice as much time as the membrane filter technique to make the same number of determinations.

TABLE I.—Activated Sludge Mixed Liquor Suspended Solids Determined by Membrane Filter Method

System No.	Substrate	Number of Samples	Sample Size (ml.)	Mean Solid Concentration (mg./l.)	Standard Deviation (mg./l.)
1	Settled domestic sewage	20	25	526	± 7.1
2	Settled domestic sewage	20	25	1,292	±10.7
3	Settled domestic sewage	20	25	1,645	±22.0
4	Settled domestic sewage	20	25	2,274	±14.2
5	Settled domestic sewage	20	25	2,944	±28.8
6	Settled domestic sewage	20	25	3,837	±13.0
7	Settled domestic sewage	10	25	4,746	±37.0
8	Synthetic sewage	25	50	276	± 7.8
9	Synthetic sewage	20	25	1,012	±16.7
10	Synthetic sewage	20	50	1,046	± 9.5

TABLE II.—Comparison of the Gooch Crucible and Membrane Filter Methods

Method	Number of Samples	Sample Size (ml.)	Mean Solid Conc. (mg./l.)	Standard Deviation (mg./l.)
Membrane filter	20	25	2,944	±28.8
Gooch crucible	20	25	2,972	±48.6

The membrane filter was also used to determine the suspended solids in a raw sewage sample. Using 25-ml. portions, an analysis of 15 determinations gave a mean suspended solids content of 294 mg. per liter with a standard deviation of ± 14.2 mg. per liter or 4.8 per cent.

In addition to the sampling error, the membrane filter technique is affected by the usual drying and weighing errors. Using five different aluminum dishes, each containing a filter membrane, 8 different drying and weighing conditions were evaluated over a continuous period of time, as noted in Table III. The data in Table III show that there was little change in weight in any one procedure. For ease and convenience of analysis, condition No. 1, with a 1-hr. drying period at 103° C. and re-exposure to atmospheric conditions for 15 min., is recommended. The data indicate that with this procedure the maximum weight change was 0.0004 g. With a 25-ml. sample, this would result in an error of 16 mg. per liter. Considering that one-half the data in Table I yielded standard deviations of less than 16 mg. per liter, the drying and weighing error in many of the samples must have been negligible.

It was also found in this study that when plain or unlined membranes were used that they were weightless when ashed at 600° C. Therefore, it is possible to determine the volatile and fixed suspended matter with this method.

Discussion

The errors and technical difficulties inherent to the Gooch crucible method of determining suspended solids have been recognized ever since the method was proposed. In fact, the 7th edition of "Standard Methods for the Examination of Water and Sewage" indicated that an error of 10 per cent or greater was not uncommon with this determination (5). This was attributed to the difficulties in collecting

TABLE III.—Change in Initial Weight of Aluminum Weighing Dish Plus Filter Membrane Under Varying Conditions

Condition		Dish Weight (g.)				
No.	Description	No. 1	No. 2	No. 3	No. 4	No. 5
1	Initial weight under atmospheric conditions without initial drying	1.5332	1.5436	1.5358	1.4988	1.3841
2	Dried at 103° C. for 4.5 hr. and cooled for 1 hr. in desiccator	−0.0002	−0.0007	−0.0007	−0.0006	−0.0001
3	Same as condition 2, then exposed to atmospheric conditions for 1 min.	−0.0002	−0.0006	−0.0006	−0.0006	−0.0001
4	Same as condition 3, then exposed to atmospheric conditions for 15 min.	−0.0001	−0.0003	−0.0004	−0.0004	−0.0002
5	Same as condition 4, then replaced in desiccator for 18 hr.	−0.0004	−0.0006	−0.0008	−0.0007	−0.0005
6	Same as condition 5, then redried at 103° C. for 1 hr. and cooled in desiccator for 1 hr.	−0.0005	−0.0006	−0.0007	−0.0007	−0.0007
7	Same as condition 6, then exposed to atmospheric conditions for 6 days	−0.0010	−0.0011	−0.0014	−0.0012	−0.0009
8	Same as condition 7, then exposed to atmospheric conditions for 14 days	−0.0009	−0.0008	−0.0013	−0.0010	−0.0009

the original sample and in withdrawing a portion for filtration. Furthermore, because of the technical difficulties and the time requirement associated with this method, other methods for determining suspended solids have been proposed, including the centrifuge, specific gravity, aluminum dish, and filter paper methods.

In comparing the centrifuge, specific gravity and aluminum dish methods, Smith (6) found the aluminum dish method was the most accurate. Using activated sludge, duplicate determinations with this method yielded results which checked "within 20 to 50 p.p.m. in 2,000 p.p.m." The accuracy of the other two methods was found to depend primarily on the characteristics of the sludge.

Regarding the Gooch crucible method, Setter (7) reported in 1949 that 15 separate determinations for total suspended solids on an unhomogenized raw sewage sample by five different laboratories gave a standard deviation of 16.8 p.p.m. or 10.7 per cent.

In proposing the filter paper method for determining raw sewage suspended solids, Fraschina (8) found that this method was superior to the standard Gooch crucible method in time required for filtration and ease of manipulation. He also found that there was no significant difference in the accuracy between the two methods for raw sewage, but that there was a difference with primary effluents.

Regarding the determination of solids in sewage and industrial wastes, the 10th edition of "Standard Methods for the Examination of Water, Sewage and Industrial Wastes" states that the accuracy cannot be determined because there is no universal standard for comparison (1). Therefore, only the precision for each analytical method can be expressed.

For sewage and industrial waste suspended solids, the best method is the Gooch crucible (1). Three different analysts, who made 65 separate sets of analyses of 10 determinations each, found that this method gave a standard deviation of 1.4 mg. Assuming that the sample size varied from 50 to 100 ml., the standard deviation would be 28 and 14 mg. per liter, respectively. An analysis of raw sewage by the membrane filter technique yielded a mean suspended solids content of 294 mg. per liter and a standard deviation of $\pm$ 14.2 mg. per liter using 25-ml. samples. This agrees with the precision reported for the Gooch crucible method. However, considering the difference in sample size, there is greater precision with the membrane filter method.

According to "Standard Methods for the Examination of Water, Sewage and Industrial Wastes," activated sludge mixed liquor suspended solids can be determined by the aluminum dish method (1). Using this method, the standard deviation on a 100-ml. sample was found to be 0.6 mg., based on the analysis of 21 separate sets of 10 determinations each. Table I shows that generally the membrane filter method yielded standard deviations less than 1.6 per cent for both the domestic sewage and synthetic sewage systems. Because of the difference in sample size, the standard deviations or precision for both methods, expressed as milligrams per liter, are not comparable.

Table I shows that when the sample size is increased, the standard deviation is decreased. This is related to the fact that with larger samples, the sampling error is reduced. Thus, in comparing various methods of analysis, sample size must be taken into consideration.

One of the questions most often asked in connection with the use of membrane filters is, "What is the effect of humidity on the results?". The membrane filters used in these studies were 47 mm. in diameter and 150 microns in depth, yielding a volume of 0.26 cc. per filter. The membrane

filter is approximately 80 per cent voids. With air at 100 per cent humidity and at 25° C. the increase in weight compared with the weight of a completely dry filter would be only 4.8×10^{-6} g. per filter. This weight difference is not significant in suspended solids analyses. Therefore, variations in humidity during the analyses will have no effect on the results and can be ignored.

There are two disadvantages associated with the membrane filter method. The first is related to the poor filterability of dispersed activated sludge. Poorly formed sludge in a dispersed state rapidly clogs the filter membrane and, thus increases the time required for filtration. However, since such activated sludge is abnormal and occurs infrequently, this does not represent a major difficulty.

The second disadvantage is one of economics. The price of the individual filter membranes represents the primary obstacle in the acceptance of this method. Compared with the presently accepted methods for the routine determination of mixed liquor suspended solids, the cost is very high. This initial cost is offset slightly by the shorter time required for analysis. However, it is doubtful if the difference in labor cost would be sufficient to warrant acceptance of this method for routine analysis; but for research studies, the membrane filter method is superior to all other methods and worth the additional expense.

Summary and Conclusions

In addition to the technical ease and rapidity offered by the membrane filter method, the precision in the determination of activated sludge mixed liquor suspended solids was greater than that reported for the methods given in the 10th edition of "Standard Methods." The standard deviations with activated sludge suspended solids, ranging from 276 to 4,746 mg. per liter were for the most part less than 1.6 per cent. Data were also given to show that this method can be adapted to the suspended solids analysis of raw sewage.

The high cost of the filter membrane was considered to be the only detrimental factor associated with its use in routine analyses.

Acknowledgment

This investigation was supported in part by a research grant from the USPHS Division of Research Grants and Fellowships, National Institutes of Health. A number of the filter membranes used were supplied by the Millipore Filter Corp., Watertown, Mass.

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EXPERIMENTAL LAGOONING OF RAW SEWAGE*

By Joe K. Neel and Glen J. Hopkins

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The lagoon method of sewage treatment in the United States apparently originated with emergency discharge of sewage to a basin dug in an old creek bed at Santa Rosa, Calif., in 1924. Purification noted in this pond, and later in impounded summer sewage at Vacaville, Calif., led to use of such facilities at several California municipalities. Early history and development of oxidation ponds in California and Texas are described by Gillespie (7), Caldwell (4), Pearse (16), Giesecke and Zeller (6), and Smallhorst, Walton, and Myers (20).

Raw sewage lagoons have been operated successfully at several North Dakota municipalities and the State Health Department recommends and approves this type of sewage treatment (24). A lagoon put into operation at Fessenden, N. Dak., in 1928, is still performing satisfactorily. Experience in North Dakota suggests a 10-acre lagoon of 4-ft. depth for each 1,000 people, or a capacity of about 200 times the daily sewage flow. Lagoons have also operated satisfactorily in South Dakota, and the State Department of Health issued minimum standards for their construction and operation in December 1953. Revised minimum standards of November 1955 incorporate all features now considered to be good lagoon practices in the Dakotas.

Investigations of lagoon processes are limited in number and mainly concerned with California oxidation ponds. Detailed studies of organisms and processes operative in ponds were conducted by Silva and Papenfuss (19), Allen (1), and by Oswald, Gotaas, Ludwig, and Lynch (9)(10)(13). In 1955 Oswald and Gotaas (14) proposed design criteria related to waste load.

Successful lagoon operation in the Dakotas aroused interest in that type of sewage treatment in neighboring states. The city of Kearney, Nebr., made inquiry into possibilities of adapting the lagoon method to its treatment needs. The Lower Platte Water Quality Investigation (2) indicated that Kearney needed to provide a minimum of primary treatment for stream sanitation in the Platte River. The North Dakota recommendation of about one acre of lagoon for 100 people would have necessitated at least 100 acres at Kearney. Because of the extreme porosity of the sandy soil in the Platte Valley, maintenance of such a body of water would require expensive soil impermeabilization. The city, although interested in testing the lagoon method, was hardly prepared to initiate operations on that scale. After consultation with representatives of the Nebraska Department of Health and the Water Supply and Water Pollution Control Program, USPHS, the city decided to embark upon an experimental program designed to determine suitability of the lagoon method under local soil and weather conditions, and capacity requirements for its waste load.

Representatives of the city and health agencies agreed upon a cooperative study in which the city of

*A cooperative study by the city of Kearney, Nebr., the Nebraska State Department of Health, and the U. S. Public Health Service.

Kearney constructed the lagoon, provided laboratory space and services of its city sanitarian for routine sample collection and analyses, and maintained discharge records of inflow and effluent; the Nebraska State Department of Health assisted in equipping the laboratory and furnished personnel for special investigations; and the USPHS provided training for the city sanitarian, engineering and biological services, and prepared a report on the investigation.

The only site readily available for location of a lagoon was a sand and gravel area near Kearney Branch. Suitability of this soil type was questionable. Still, it appeared that some sealing would be affected by sewage solids, and it was assumed that seepage through the bottom would go toward the adjacent canal. Site of the nearest domestic use of ground water appeared sufficiently remote to escape any possible bacterial contamination from the lagoon.

Objectives of the study were determination of the suitability of the soil type, possible effect of the lagoon upon ground water, applicability of the lagoon method for the waste load and geographical location, and the proper size facility for adequate waste treatment. Inquiry into the nature of lagoon processes was adjudged as important as estimation of its performance, so the study was designed to permit as much insight into lagoon processes as possible under the circumstances.

General Plan of Operation

It was assumed that lagoon capacity required for adequate waste treatment could be determined by varying the sewage load and observing performance of the 10-acre unit under varied load and weather conditions. Neglecting seepage, use of all sewage would allow about 10-day retention, one-third of the total flow would give 30 days, etc. All sewage would be turned into the lagoon until a satisfactory depth was attained, then only a selected fraction of the total sewage volume would be admitted. When proper loading for the experimental structure was evident, a permanent facility could be designed on the basis of the indicated desirable load per unit area or volume.

Difficulties encountered in obtaining a seal, and unexpected early cessation of lagoon operation, following objections to detergents in ground water, did not permit complete realization of the planned schedule of operations. Sufficient depth to allow overflow did not develop until September 1954, and operation with a reduced load was possible only during fall, winter and the following spring. It was necessary, also, to bypass the entire sewage load upon several occasions.

Lagoon performance was evaluated by biweekly grab samples for pH, alkalinity, oxygen, B.O.D., turbidity, settleable solids, and coliform analyses. Twentyfour-hour composites indicated average daily loadings in summer and winter. Biological study was based upon plankton and bottom samples. Details of sampling and analysis procedures appear in later sections of this paper.

Wastes at Kearney

The 1950 population of Kearney totaled 12,115; about 10,500 inhabitants were connected to a long outfall line that discharges to Kearney Branch approximately four miles southeast of the city (Figure 1). Sewered industries, produce houses, poultry dressers, creameries, and dairies were estimated (2) to have a total population equivalent of 2,225. Organic wastes were therefore assumed to be equivalent to those from 12,725 persons. Kearney's water supply consists of untreated ground water pumped from 9 wells.

Sewage usually reached the outfall in an anaerobic state and was normally malodorous. The strongest wastes were discharged in early afternoon and the

FIGURE 1.—Sewage lagoon area at Kearney, Nebr.

most dilute condition was evident from 7:00 to 11:30 AM. Average sewage discharge was about 1.32 m.g.d.

Lagoon Description

The lagoon was excavated near the northern edge of a river-deposited sand and gravel area about four miles southeast of Kearney (Figure 1). Irrigated crop lands extend to the north and east, and land to the west is used as pasture. Irrigation water is obtained from an underground aquifer at pumping sites shown in Figure 1.

Lagoon dikes were formed with excavated sand and gravel. They were raised about 8 ft. above the ground level and enclosed an area slightly greater than 10 acres. The concrete pipe inlet line (Figure 2) extended to the lagoon center. Excavation entered the ground water table; ditching being very difficult, the inlet line was banked with sand and gravel. Discharge was lateral. Sewage was diverted to the lagoon through a Parshall flume that connected, with provision for bypass, to the old outfall line (Figure 2). A stage recorder was housed in a small building on top of the flume.

The outlet structure consisted of two open upright 8-in. iron pipe sections connected to two 8-in. lines (Figure 3) that joined above an 8-in. impeller-type flow meter to a single 8-in. line leading to the canal. The upright sections were housed in a concrete box with a screened open side facing the lagoon. They were set to draw off water above the 3.75-ft. mark. The meter was housed in a manhole in late September and the effluent line was covered with sand and gravel.

Operation

Essential features of lagoon operation—daily inflow, effluent volumes, and depth variation—appear in Figure 4. A high rate of infiltration into the sand and gravel bed was expected, so the entire volume of sewage was turned into the lagoon in mid-May to gain benefit of all sewage solids in obtaining a seal. Seepage was little hindered, and did not slow sufficiently to permit effluent discharge until Sep-

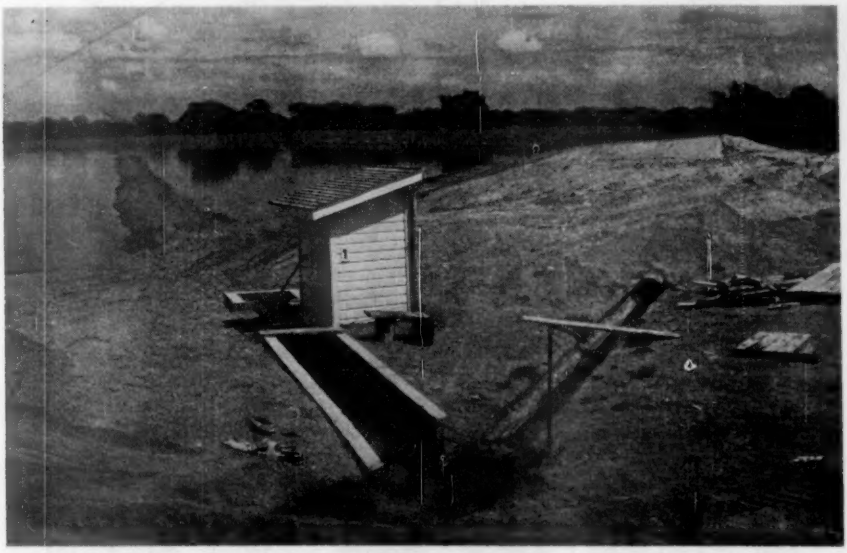

FIGURE 2.—Lagoon, inlet line, Parshall flume, stage recorder house, and bypass line.

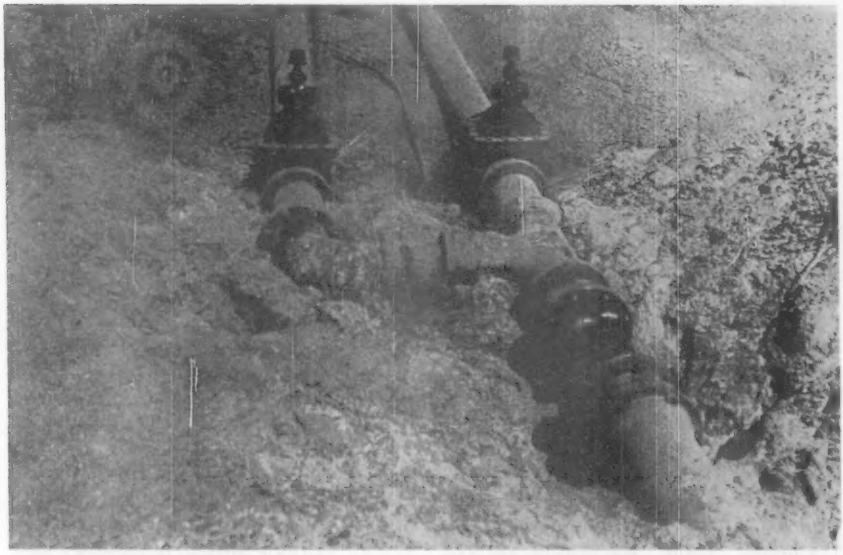

FIGURE 3.—Effluent lines joining above meter on discharge pipe.

tember. On May 15, 1954, 6 in. of ground water covered the lagoon floor. The water level remained at or near this elevation during May and June, and permitted retention of a shallow layer of wastes and early establishment of purification processes. Total lagoon capacity approximated the volume of sewage for a 10-day period.

Percentage loss to ground and evaporation (Table I) varied. During summer and early fall this variation was to a large extent the result of fluctuation in ground water level, which was influenced by irrigation pumping, weather, and discharge in the nearby streams. Some sealing of the lagoon bottom had been effected

TABLE I.—Relationships of Influent Sewage Volume to Seepage and Effluent Discharges

Period	Sewage Put into Lagoon (gal.)	Sewage Retained in Lagoon (gal.)	Effluent (gal.)	Sewage Retained in Lagoon (%)	Liquid Discharged (%)	Ground and Evaporation Loss (%)
5/15–31/54	19,356,593	651,700	0	3.4	0	96.6
6/1–30/54	42,590,406	4,236,050	0	9.9	0	90.1
7/1–31/54	51,597,743	2,118,025	0	4.1	0	95.9
8/1–31/54	46,003,020	3,095,575	0	6.7	0	93.3
9/1–30/54	33,242,196	651,700	3,659,040	1.9	11.0	87.1
10/1–31/54	34,232,484	−325,850	14,994,900	—	43.8	56.2
11/1–30/54	8,100,000	162,925	7,016,163	2.0	86.6	11.4
12/1–31/54	9,900,000	553,945	2,851,200	5.6	28.8	65.6
1/1–31/55	8,750,000	1,042,720	3,065,351	11.9	35.0	53.1
2/1–28/55	9,800,000	32,585	4,825,273	0.3	49.2	50.5
3/1–31/55	10,860,800	0	4,089,680	0	37.6	62.4
4/1–30/55	11,537,966	0	7,127,966	0	61.7	38.3
5/1–31/55	11,787,864	0	7,168,865	0	60.8	39.2
6/1–30/55	14,196,805	325,850	9,726,805	2.3	68.5	29.2
Total	311,955,877	12,545,225	64,525,243	4.0	20.7	75.3

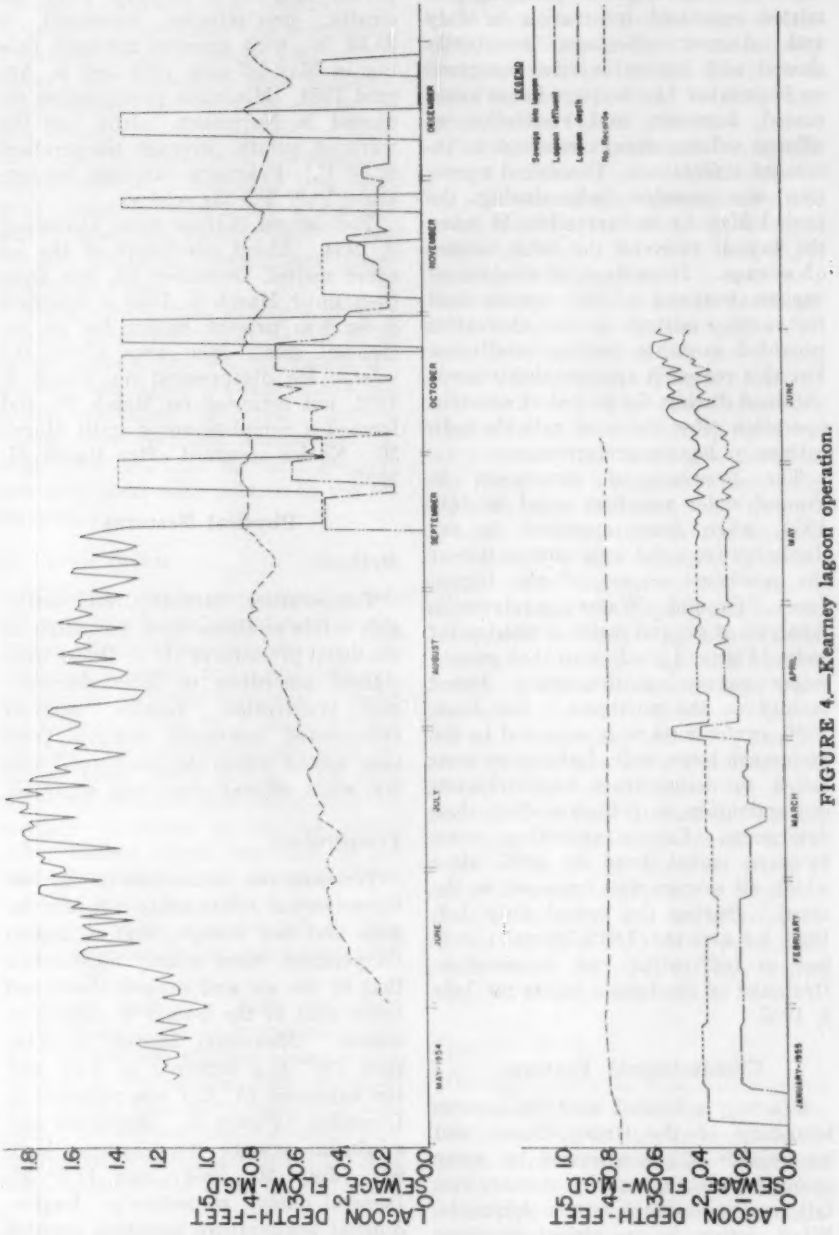

FIGURE 4.—Kearney lagoon operation.

by June 30, but a lowering of ground water level by irrigation pumping permitted increased infiltration in July and August. Seepage eventually slowed and lagoon overflow occurred on September 14. Seepage losses never ceased, however, and restriction of effluent volume always resulted in increased infiltration. Consistent operation was possible only during the period May 15 to September 14 when the lagoon received the total volume of sewage. Inconstant admissions of various portions of the sewage load for varying periods of time thereafter provided unstable loading conditions. For this reason it appears that records obtained during the period of constant operation offer the most reliable indications of lagoon performance.

The presence of detergents in ground water was first noted in July 1954, when foam appeared in the discharge from the irrigation well near the northeast corner of the lagoon (see "Ground Water Analyses"). Analysis of ground water at sand point wells (Figure 1) indicated that ground water containing detergents flowed mainly to the northeast. By June, 1955, surfactants were reported in the Steinmark house well. Laboratory tests failed to demonstrate bacteriological contamination or pollution other than detergents. Lagoon operations were, however, ended June 30, 1955, after which all sewage was bypassed to the canal. During the period July 1–7, 1955, 3.2 acre-ft. (1,042,720 gal.) were lost to infiltration and evaporation. Drainage of the lagoon began on July 8, 1955.

Climatological Features

Kearney is located near the eastern boundary of the Great Plains, and its weather is characterized by many sunny days during spring, summer and fall, and occasional winter blizzards. Wind action is an almost constant feature. The mean annual rate of evaporation is about 51 in. from shallow lakes and reservoirs. During the period May 1954 to May 1955, inclusive, precipitation amounted to 25.63 in., with greatest amounts falling in May of each year and in August 1954. Minimum precipitation occurred in November. July was the warmest month (average temperature 82.7° F.), February (average temperature 18.9° F.) the coldest.

The lagoon surface froze December 3, 1954. About one-fourth of the ice cover melted December 23, but from then until March 3, 1955 a complete cover was present except for an occasional small open area above the inlet. Ice disappeared on March 8, 1955, but returned on March 20, and formed a complete cover until March 30. No ice occurred after March 31, 1955.

Physical Features

Methods

Temperature, turbidity, and settleable solids analyses were according to the usual procedures (21). Odors were classed according to their character and penetration. Lagoon analyses represented composite samples from sites spaced across the pond until winter, when effluent alone was analyzed.

Temperature

Temperature measurements showed the expected relationship between lagoon and raw sewage; that is, lagoon temperature more closely approached that of the air and ranged above and below that of the sewage according to season. Maximum lagoon temperature (34° C.) occurred in July and the minimum (1° C.) was recorded in December (Figure 6). Maximum and minimum sewage temperatures were 27° (July 30, 1954) and 11.5° C. (several dates), respectively. Lagoon diurnal temperature variation covered a greater range than that of the sewage.

Turbidity

Lagoon turbidity was primarily influenced by plankton concentration. Turbidity in upper ranges (550 to 700 p.p.m.) was associated with plankton densities near the observed maximum, and lower range turbidities (less than 25 p.p.m.) coincided with low plankton concentrations. Turbidity declined with plankton growth in September and October and increased again when denser plankton populations reappeared in April.

Sewage turbidities averaged greater (range 25 to 450 p.p.m.) than those of the lagoon, but did not attain the lagoon maximum. Considerable diurnal variation occurred. Lowest values were recorded during the period 7:00 to 11:30 AM and greatest concentrations were present in the afternoon.

Settleable Solids

With few exceptions settleable solids were practically nonexistent in the lagoon waters. Plankters showed little tendency to settle, and never left suspension in sufficient numbers to build up more sediment than about 0.2 ml. per liter. Values above this level resulted from other solids that were probably brought into suspension by sampler operation in shallow areas. After lagoon depth increased to the overflow level, and samples were mainly from the effluent, settleable solids only once exceeded 0.1 ml. per liter. Lagoon effluent averaged 0.0053 ml. per liter.

Sewage showed a daily variation. Greatest amounts were generally evident during the afternoon and lowest quantities during the 7:00 to 11:30 AM period. One 24-hr. composite contained 6.0 ml. per liter. Average concentration was 5.0 ml. per liter and the maximum was 15.0.

Odors

Raw sewage odors at the lagoon inlet flume were usually unnoticeable at a distance of 50 ft. downwind. After bypass in September, stronger odors were noted at the raw sewage outfall. However, they were usually dissipated within 100 ft. Their presence in this vicinity masked any scents in the lagoon effluent.

Lagoon odors developed during extended periods of anaerobiasis. Floating solids accumulations gave off slight odors, which never endured more than a few yards beyond the dikes, from June until September.

Anaerobic conditions over 24-hr. periods were rarely encountered until early October. From October 1 until April 10, oxygen depletion was the rule with only five exceptions, and local odors developed during open water periods. The scent was occasionally like that of a pigpen, but normally a sulfide odor prevailed. By October 2, odors were evident in the immediate vicinity of the lagoon. They endured until November 26, when a small number of phytoplankters effected an 8 per cent oxygen saturation. The lagoon surface froze on December 3 and no odors were detectable until December 23, when about one-fourth the ice cover melted and freed another scent. From then until March 8, complete or nearly complete ice cover allowed little odor liberation. The ice disappeared completely March 8, but returned on March 20, after which it endured until March 31. A locally disagreeable odor was thereafter present until April 13. No objectionable odors were reported in the period April 13 to June 30, 1955.

Floating Solids

Sewage solids at first accumulated in the northwest corner of the lagoon. Their build-up in this area was facilitated by extremely shallow water and partial division caused by the banked inlet pipe (Figure 2), which separated the narrow northwest section into two coves and permitted outward water movement only to the southeast.

Solids caught on the bottom decomposed and furnished lighter elements that rose to the surface and gradually formed a large floating mat of putrescible substances. Floating solids were swept from the two coves by northwest winds and later moved from shore to shore by changing air currents. Formation of floating materials slowed after water covered the inlet line, but new masses continued to appear in the northwest corner until late summer. Presence of these solids was recognized as a threat to desirable lagoon processes and for some time they were raked out and buried when wind-blown to shore, or broken up by hosing. They declined sufficiently to be safely ignored in late summer. In July some shallow water in the northwest corner was eliminated by extending the dike about 10 ft. into the lagoon.

Floating solids were malodorous, but their stench was always restricted to their immediate vicinity and was not evident beyond the dikes. The floating mats frequently contained clumps of blue-green algae that had become detached from shallow areas near the water line and green algae from plankton. They seldom covered an area greater than one-half acre.

Organic Bottom Deposits

Dredge sampling was started in late summer. At that time the bottom was largely covered by a thin layer of oozy gelatinous material that contained numerous algae and other organisms. Black sewage solids formed a layer about 3 in. thick in the northwest corner. Later dredging disclosed almost the same state of affairs. The algae disappeared in late fall, but noticeable accumulation of sewage solids was always restricted to the northwest region. Deposits in this area did not increase in depth, and their presence was assumed to have resulted from immobilization during the early life of the lagoon.

Circulation

Successful functioning of a lagoon of this type depends upon mixing of upper water into lower layers to provide adequate oxygen concentration at all depths. Wind-driven circulation forms the basis of this mixing process, the vertical extent of which rests upon the relationship of area to depth. In a 10-acre pond, circulation may be expected to extend to a depth of 4 ft. in regions of frequent or almost continual air movement. The Kearney lagoon was designed on this basis, and its circulation, as exhibited by oxygen concentration at surface and bottom, always appeared nearly complete.

Mixing was attained despite an almost complete absence of waves or ripples at all wind velocities. The push of wind on the surface raised the water level on the leeward side and so induced backflow along the bottom toward the windward side. Surface backflow was frequently observed at the pond margins. In May and June 1954, when southeast winds drove water into the two coves on either side of the inlet line, dense accumulations of algae frequently moved to the southeast in narrow bands on either side of the pipe embankment. Velocity of these alongshore currents varied from 0.3 to 0.7 f.p.s.

The failure of the lagoon surface to develop ripples or waves under stress of wind action has not been related to any definite component. It had nothing to do with protection from the wind; nearby gravel pits, which were less exposed, rippled or developed waves with all air movements. The lagoon's failure to behave in a normal fashion was suspected to be due to detergents, which may have lowered surface tension and viscosity. From the behavior of lagoon water in pipettes, it is known that surface tension was lowered. Coin *et al.* (5) found that detergents measurably lowered the surface tension of surface waters.

Appearance

The lagoon quickly developed a green color, which it retained with few interruptions from May until late September. Periods of cloudy weather induced a plankton decline and occasionally the color was grayish white. The surface gave off a faint odor at such times. Redevelopment of phytoplankton frequently resulted in streaks of gray and green for about a day after recurrence of sunny weather. Until uniformity was attained the deepest green color usually appeared near the leeward shore. During the extended anaerobic period (October 1954 to April 1955) water color was dark brown, little modified by turbidity.

The only unsightly feature was floating solids, which were generally concentrated in one corner or along one side. The lagoon surface was not visible from the road along the eastern boundary, and the solids, which covered only small areas of the pond, could hardly qualify as detrimental to aesthetic values of the neighborhood.

Chemical Features

Methods

Analyses were according to "Standard Methods" (21). The majority of lagoon analyses were performed upon composites made from four samples spaced across the pond. Oxygen analyses were performed on each of the four samples for about three months. During winter months analyses were restricted to lagoon effluent.

Oxygen

Oxygen was present in sewage only about 4.5 hr. (7:00 to 11:30 AM) each day. The observed maximum concentration was 3.96 p.p.m.

Lagoon oxygen supply depended chiefly upon photosynthesizing algae, whose activities provided quantities in excess of demands during daylight. Maximum concentration observed was 480 per cent of saturation (Figure 6). When photosynthesis slowed during cloudy weather, or stopped at night, oxygen usually disappeared within a few hours. Highest daily concentrations were attained in late afternoon and depletion generally occurred before dawn. Occasionally the supply was not exhausted at dawn, and sometimes it was used up during early hours of darkness.

In summer and early fall, algae maintained oxygen levels high enough to prevent occurrence of extended anaerobic periods. Photosynthesis slowed in mid-October 1954, and was seldom able to furnish oxygen supplies in excess of immediate demands from then until April 1955. Reaeration from the atmosphere could satisfy only a fraction of the demand, and the lagoon remained anaerobic, except for short periods, until spring.

Oxygen was not uniformly distributed throughout the pond. When present anywhere it occurred in all areas and at all depths, but its concentration differed at various sites with wind direction, distance from the windward shore, and from the point of raw sewage discharge. Samples during August, September and October, 1954 were collected along transects extending from the windward to the leeward side of the lagoon. Four equally spaced samples, numbered 1, 2, 3, and 4, in order, from windward to leeward, were collected along each line. Results are given in Table II.

Wind action drove surface water to the leeward shore and induced backflow to windward along the bottom. Upwelling bottom water, which had been below the layer penetrated by light, was responsible for lower oxygen values near the windward shore. As this water moved along the surface, algae suspended in it renewed photosynthesis and increased oxygen content. On three occasions oxygen showed a progressive build-up across the entire distance. Raw sewage up-

TABLE II.—Oxygen Concentration (P.P.M.) Along Windward to Leeward Transects

Date (1954)	Sampling Position Oxygen Concentrations (p.p.m.)			
	No. 1	No. 2	No. 3	No. 4
Aug.				
6	4.4	2.6	5.6	5.6
9	16.0	23.8	35.8	29.6
16	4.2	7.1	2.3	2.8
20	20.0	27.0	30.0	28.0
23	16.6	24.8	23.8	29.6
27	17.0	27.6	34.2	29.0
Sep.				
10	23.8	26.6	28.2	28.2
13	13.2	13.8	13.6	11.0
17	7.6	9.5	8.1	8.9
20	6.8	9.8	9.6	12.2
21	19.1	19.9	16.1	21.3
24	8.4	12.0	9.0	—
27	13.2	16.0	21.0	23.6
Oct.				
1	0.9	2.4	1.3	4.1
4	0.4	1.45	1.7	1.9
11	0.75	6.9	6.75	6.0

welling from the inlet often caused a decline at the third, rarely at the second, sampling station. Yet, decreases close to the center were usually followed by increases nearer the leeward bank. Declines at the fourth station occurred when masses of floating solids drifted to the lee shore.

Few samples were taken at various depths. Values near the bottom were consistently lower than those at the surface, but were never 0.0 unless oxygen was absent at all depths. Wind mixing, therefore, always appeared sufficient to prevent stagnation at the bottom. Concentration at the bottom varied up and down with that near the surface.

Biochemical Oxygen Demand

Sewage B.O.D. reached its greatest concentration in the early afternoon and then steadily declined until around 7:00 AM the following day. Concentration was lowest during periods of maximum water use in summer and highest when sewage volume decreased in fall and winter (Table III). Values of 24-hr. composites were 123 p.p.m. in summer and 189 in winter. The average of all grab samples was 149 p.p.m.; because grab samples were taken at all hours of the day, and two to six times per week, their average is considered quite representative of the sewage. Average sewage volume was 1,317,563 g.p.d. The mean daily B.O.D. load (based on 149 p.p.m.) amounted to 1,637 lb. This poundage equals wastes from 9,802 people (assuming 0.167 lb. of B.O.D. per capita per day). The load was lower than indicated by the sewered population and estimates of industrial wastes.

Sewage and lagoon B.O.D. averages and reduction of sewage B.O.D. during various phases of operation appear in Table III. Reduction in B.O.D. comparable to conventional secondary treatment was afforded by theoretical 10-day retention during weather conditions favorable to photosynthesis. Major control of the treatment process was exerted by weather and not by sewage load. Climatological conditions that restricted light penetration resulted in lagoon processes that were incapable of a comparable reduction in oxygen-consuming power when only one-third of the sewage was introduced.

Lagoon B.O.D. was measured with diluted samples. Values so obtained indicate reduction of sewage B.O.D. but probably offer an exaggerated picture with regard to effluent deoxygenation effect upon receiving waters. Incubated samples did not show the oxygen demand exerted by the lagoon and its biota *in situ*, and possible loss to the atmosphere, when the main source of oxygen supply (photosynthesis) was slowed or halted. Oxygen utilized by lagoon water in its natural environment should not be considered a measure of the oxygen consuming power of its effluent, since a change of environment appeared to reduce amounts of oxygen consumed in darkness. Deoxygenation effects of the effluent upon receiving waters is considered even less than indicated by the

5-day B.O.D., because algae normally present continue photosynthesis and add to oxygen supplies during daylight. Yet, oxygen used by lagoon water *in situ* largely determines the degree of oxygen surplus or deficit and the likelihood of odor nuisance during open water seasons. Odor production did not indicate a lesser 5-day B.O.D. reduction, but only a lack of oxygen. On November 17, when a strong odor was reported, the lagoon 5-day B.O.D. was 35 p.p.m. On October 11, when oxygen was present, B.O.D. was 45 p.p.m. On November 26 odor disappeared and B.O.D. was 22 p.p.m. On March 17 no odors occurred when B.O.D. was 68 p.p.m.

It appears that B.O.D. measurement of algae-laden water does not offer a true index of the amount of stabilization afforded by incorporation of waste materials into bodies of living organisms. Behavior of such organisms in a darkened incubator deviates considerably from their actions in receiving streams. Parker *et al.* (15) noted significant reduction in measured B.O.D. of lagoon effluents when algae were filtered out.

Pounds B.O.D. removal per acre per day (Table IV) was computed on the assumption that displacement to the ground and effluent line was equivalent to the daily sewage inflow. Evaporation, a constant factor affecting lagoon efficiency, was not considered in this respect.

Greatest poundage removal (173 lb. per acre per day) was effected with heaviest loading, as would be expected, but on a percentage basis load per

TABLE III.—Average Sewage and Lagoon B.O.D. During Various Operational Phases[1]

Period	B.O.D. (p.p.m.)		B.O.D. Reduction (%)	Conditions
	Sewage	Lagoon		
(1954)				
Jun. 14–Sep. 14	122	22	82	All sewage into lagoon
Sep. 15–22	174	18	90	Two-thirds sewage bypassed
Sep. 23–29	160	23	86	All sewage into lagoon
Sep. 30–Oct. 4	167	23	86	Two-thirds sewage bypassed
Oct. 5–22	161	42	74	All sewage into lagoon
Oct. 23–24	—[2]	—[2]	—	All sewage bypassed
Oct. 25–30	193[3]	39[3]	80	All sewage into lagoon
Oct. 31–Nov. 4	300[3]	31[3]	—	All sewage bypassed
Nov. 5–16	204	43	79	Two-thirds sewage bypassed
Nov. 17–23	137	35	—	All sewage bypassed
Nov. 24–26	203	22[3]	89	All sewage into lagoon
Nov. 27–Dec. 9	189	18[3]	—	All sewage bypassed; ice cover Dec. 3
Dec. 10–15	138	27[3]	80	All sewage into lagoon; ice cover
Dec. 16–23	133	38	—	All sewage bypassed; ice cover
Dec. 24–27	—[2]	—[2]	—	Two-thirds sewage bypassed; ice cover
Dec. 28, 1954–Jan. 5, 1955 (1955)	199	—[2]	—	All sewage bypassed; ice cover
Jan. 6–Mar. 8	138	94	32	Two-thirds sewage bypassed; ice cover until Mar. 8
Mar. 9–19	130	68	48	Two-thirds sewage bypassed; ice cover gone, but comes partially on again
Mar. 20–29	131	58	56	One-half sewage bypassed
Mar. 30	—[2]	—[2]	—	All sewage into lagoon
Mar. 31–Apr. 3	113	45	60	One-half sewage bypassed
Apr. 4–Jun. 13	143	36	75	Two-thirds sewage bypassed

[1] Data supplied by city of Kearney.
[2] No data.
[3] Only one record.

TABLE IV.—B.O.D. Applied and Removed per Acre per Day

Period	B.O.D. (lb./acre/day)		B.O.D. Removal (%)	Operation
	Loading	Removal		
(1954)				
Jun. 14–Sep. 14	157	128	82	All sewage to lagoon
Sep. 15–22	66.5	59.6	90	Two-thirds sewage bypassed
Sep. 23–29	183	156.5	85.5	All sewage to lagoon
Sep. 30–Oct. 4	63.5	54.7	86	Two-thirds sewage bypassed
Oct. 5–22	181	134	74	All sewage to lagoon
Oct. 25–30	217	173	80	All sewage to lagoon
Nov. 5–16	19.1	15.1	79	Two-thirds sewage bypassed
(1955)				
Jan. 6–Mar. 8	39	12.5	32	Two-thirds sewage bypassed
Mar. 9–19	38	18	47	Two-thirds sewage bypassed
Mar. 20–29	38	21	55	One-half sewage bypassed
Mar. 31–Apr. 3	43.5	26	60	One-half sewage bypassed
Apr. 4–Jun. 13	46	34.3	74.5	Two-thirds sewage bypassed

acre had less influence, lighter loading seemingly resulting in a greater percentage removal during comparable seasons. It may be noted by reference also to Table III that percentage of reduction on a B.O.D. concentration basis was almost identical to percentage of reduction of pounds applied per acre. During most favorable weather seasons (June to September 1954) the average removal was 128 lb. of an average applied load of 157 lb. per acre per day and lagoon water had an average concentration of 22 p.p.m. Efficiency was the same whether judged on a concentration or pounds-per-acre basis. Sewage load variation in the ranges observed apparently had little direct bearing on the quality of effluent during most favorable seasons. During unfavorable seasons heavier loadings could be expected to give heavier effluent B.O.D. concentrations.

Purification noted by Parker *et al.* (15) in Australian lagoons following anaerobic sedimentation ponds amounted to as much as 82.2 lb. of B.O.D. removed per acre per day with loadings of 272 lb. per acre per day. A loading of 289 lb. per acre per day, however, reduced removal to 54.1 lb. per acre per day. Wastes going into their aerobic lagoons were primary effluents and contained those B.O.D. fractions most difficult to remove. Parker *et al.* consider B.O.D. measurements of algae-laden effluents to be unreal, as they believe such effluents will normally tend to increase oxygen content of receiving waters.

pH

The pH values of the sewage ranged from 7.2 to 8.4. Frequently, morning pH values were higher than those of the afternoon, but this pattern was not consistent, and values above 8.0 occurred only in the afternoon.

Lagoon pH values ranged from 7.2 to 9.5 The latter value was possibly exceeded on some dates, but apparatus available most of the time permitted readings only up to 8.4. Values above 7.8 resulted from photosynthesis, which removed CO_2 from bicarbonate and produced quantities of monocarbonate. Highest pH values coincided with maximum or near maximum oxygen saturation. Diurnal variation is not known, but it may be safely assumed that pH fell below 8.0 when oxygen disappeared at night. Extended anaerobic periods often reduced pH to 7.2.

Alkalinity

Total alkalinity of the sewage averaged 447 p.p.m. Concentration was highest in winter and daily maximums occurred around 2:00 PM.

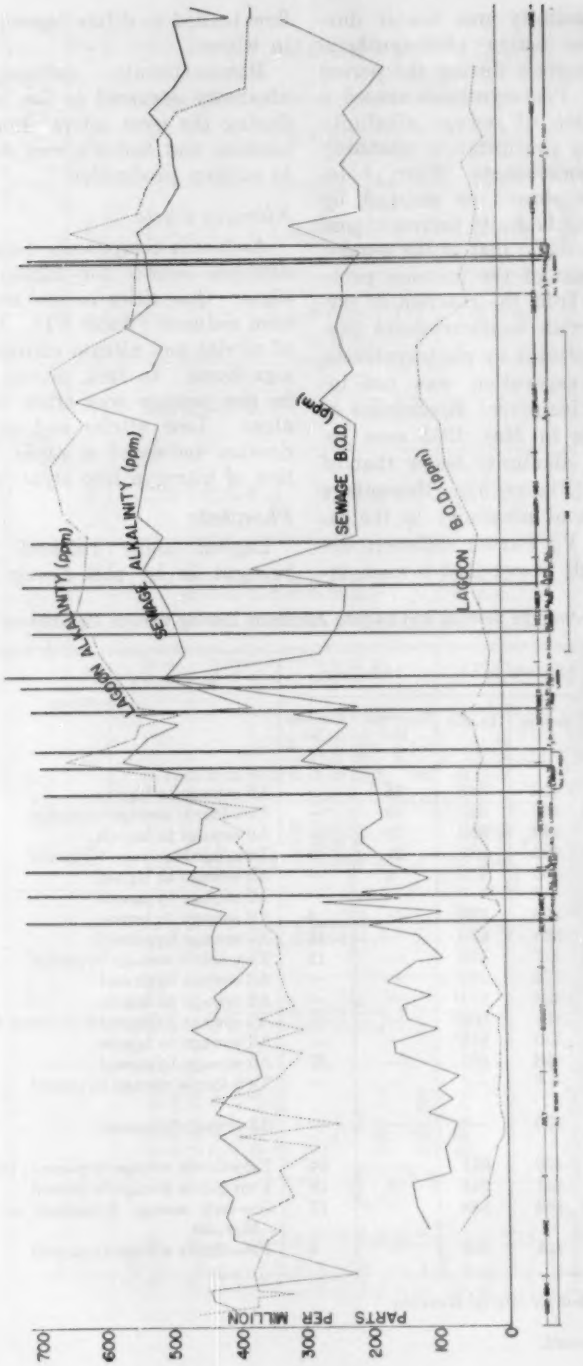

FIGURE 5.—Sewage and lagoon alkalinity and B.O.D. variation.

Lagoon alkalinity was lowest during the more active photosynthetic seasons and highest during the period of ice cover. Photosynthesis caused a sharp reduction of sewage alkalinity (Figure 5) by precipitating relatively insoluble monocarbonate. When photosynthesis was slowed or stopped by winter, lagoon alkalinity increased and eventually exceeded that of the sewage. The major part of the increase probably resulted from the reaction of carbon dioxide with monocarbonate previously precipitated by photosynthesis, as surface evaporation was not involved under ice cover. Resurgence of photosynthesis in May 1955 soon reduced lagoon alkalinity below that of raw sewage (Figure 5). Percentage loss and gain of alkalinity in the lagoon (Table V) during different operation periods shows that sewage inflow tended to dilute lagoon alkalinity in winter.

Monocarbonate (phenolphthalein) alkalinity occurred in the lagoon only during the most active photosynthetic seasons, and had a direct relationship to oxygen production.

Nitrogen Cycle

Ammonia compounds were the chief nitrogen source for lagoon plankton algae. Quantities in raw sewage were soon reduced (Table VI). Production of nitrite and nitrate nitrogen was insignificant. In fact, nitrate contained in raw sewage was often utilized by algae. Low nitrite and nitrate production indicated a rapid incorporation of nitrogen into algal protoplasm.

Phosphate

Lagoon algae reduced phosphate brought in by raw sewage, but this

TABLE V.—Average Sewage and Lagoon Alkalinity During Various Operational Phases[1]

Period	Alkalinity (p.p.m.)		Alkalinity		Conditions
	Sewage	Lagoon	Reduction (%)	Increase (%)	
(1954)					
May 20–Sep. 14	410	348	15	—	All sewage to lagoon
Sep. 15–22	445	362	19	—	Two-thirds sewage bypassed
Sep. 23–29	448	362	19	—	All sewage to lagoon
Sep. 30–Oct. 4	482	381	21	—	Two-thirds sewage bypassed
Oct. 5–22	456	419	8	—	All sewage to lagoon
Oct. 23–24	—[2]	—[2]	—	—	All sewage bypassed
Oct. 25–30	476	520	—	9	All sewage to lagoon
Oct. 31–Nov. 4	565	650	—	15	All sewage bypassed
Nov. 5–16	477	530	—	11	Two-thirds sewage bypassed
Nov. 17–23	372	542[3]	—	—	All sewage bypassed
Nov. 24–26	450	574[3]	—	—	All sewage to lagoon
Nov. 27–Dec. 9	499	600[3]	—	—	All sewage bypassed; ice cover Dec. 3
Dec. 10–15	440	612[3]	—	—	All sewage to lagoon
Dec. 16–23	458	627	—	37	All sewage bypassed
Dec. 24–27	—[2]	—[2]	—	—	Two-thirds sewage bypassed
Dec. 28, 1954–Jan. 5, 1955 (1955)	470	—[2]	—	—	All sewage bypassed
Jan. 6–Mar. 8	479	641	—	34	Two-thirds sewage bypassed; ice off Mar. 8
Mar. 9–19	461	544	—	18	Two-thirds sewage bypassed
Mar. 20–Apr. 3	460	538	—	17	One-half sewage bypassed; all to lagoon Mar. 30
Apr. 4–Jun. 13	445	458	—	3	Two-thirds sewage bypassed

[1] Data supplied by city of Kearney.
[2] No data.
[3] Only one record.

TABLE VI.—Individual Nitrogen, Phosphate, Detergent, and Chloride Records [1]

Date	Time	NH_3—N (p.p.m.)		NO_2—N (p.p.m.)		NO_3—N (p.p.m.)		PO_4 (p.p.m.)		Detergents[2] (p.p.m.)		Chloride (p.p.m.)	
		S[3]	L[4]	S[3]	L[4]	S[3]	L[4]	S[3]	L[4]	S[3]	L[4]	S[3]	L[4]
(1954)													
May 27	9:30 AM	5.7	4.5	0	0	0.2	0.3	17	35	—	—	—	—
	6:00 PM	6.4	3.6	0	0	0.4	—	42	24	—	—	—	—
May 28	8:30 AM	—	4.2	—	0	—	0.4	—	27	—	—	—	—
Jun. 9	3:30 PM	5.4	3.7	0	0	0.2	0.1	27	17	—	—	—	—
Jul. 9	9:00 AM	3.7	3.2	0	0	0.2	0.1	19	14	—	—	—	—
Jul. 24	9:00 AM	4.1	3.5	0	0	0.2	0.2	18	16	—	—	—	—
Aug. 12	9:30 AM	3.9	3.2	0	0	0.2	0.1	21	14	—	—	—	—
Aug. 31	—	2.0	0.8	0.002	0.005	0.1	0.1	—	—	16	11	68	83
Sep. 1	—	2.5	0.9	0.007	0.003	0.2	0.3	—	—	8	9	72	83
Sep. 3	—	2.2	1.0	0.007	0.008	0.4	0.15	—	—	7	9	80	84
Sep. 4	—	0.75	1.25	0.004	0.003	0.2	0.2	—	—	12	10	178	84
Sep. 21	2:00 PM	6.2	3.4	0	0	0.3	0.2	34	19	—	—	—	—
Nov. 10	—	—	—	—	—	—	—	—	—	—	—	—	93
Nov. 17	3:15 PM	20.0	16.0	0	0	—	—	30	50	—	—	—	—
(1955)													
May 12	9:00 AM	19.2	18.0	0	0	0.3	0.3	21	17	—	—	—	—
Jun. 10	—	2.5	0.9	0.005	0.005	0.2	0.4	—	—	39	17	386	113
Jun. 12	—	2.3	1.0	0.003	0.006	0.2	0.4	—	—	9	21	43	113
Jun. 13	—	—	—	—	—	—	—	—	—	36	20	59	108

[1] Detergent, chloride, and part of phosphate data courtesy of Nebraska State Department of Health. Other analyses by USPHS.
[2] Sodium alkyl aryl sulfonates.
[3] Sewage.
[4] Lagoon.

fact was not always evident in lagoon and sewage analyses performed in the early forenoon (Table VI). At that time sewage was weak in all components. Extended anaerobiasis permitted accumulation of phosphate within the lagoon.

Detergents and Chlorides

Performance of only seven detergent and chloride analyses left a somewhat contradictory picture of relationships between raw sewage and lagoon water (Table VI). Detergents were less concentrated in the lagoon on four occasions and more concentrated on three dates. Chloride exhibited greater concentration five times and lesser concentration two times. The sewage undoubtedly varied at different times of the day, and analyses at both weak and strong periods are probably responsible for contradictions noted. Times of analyses were not given.

Ground Water Analyses

This investigation phase started after foam appeared in the discharge from the irrigation pump near the northeast corner of the lagoon. Sand point wells were established at locations shown in Figure 1, and nearby gravel pits; irrigation, windmill, and house wells also were sampled.

Analyses (Table VII) indicated that detergents proceeded slowly to the northeast, extending about one-half mile in ground water (to Merryman's irrigation well) in 14 months. In other directions detergents occurred only in the immediate vicinity of the lagoon. Chloride measurements substantiated detergent results, since greater concentrations occurred at sites where detergents were recovered. Other analyses (alkalinity, nitrogen cycle, etc.) gave no clearcut indications of pollution, as it appeared normal for ground water to vary considerably in those respects. All analyses indicated full compliance with accepted chemical standards for potable water.

Wells located near the lagoon were unprotected from contamination by surface drainage from livestock and irrigated areas, and backflow of surface water into windmill and irrigation wells was noted on several occasions. Use of these wells as sampling points to check on possible penetration of coliform-type bacteria from lagoon seepage did not seem justified, as contributions from land surface areas could not be ruled out. It also was doubtful that pumps could be sterilized properly prior to sample collection. For these reasons analyses for coliform-type bacteria in ground water were not included in the planned investigation. However, a local farmer became alarmed over the appearance of detergent foam in the irrigation well near the northeast corner of the lagoon, and submitted coliform samples from his house wells to the State Department of Health laboratory.

Maximum detergent concentration in this well was 7.5 p.p.m. Cities using surface water along the Neosho River in Kansas generally have concentrations of 6 p.p.m. in finished water (*Water Works Eng.;* Dec., 1955).

Seven analyses from the Steinmark house well (six by the State Department of Health laboratory and one by Harris Laboratories of Lincoln, Nebr.) showed coliform organisms to be present on only two occasions, May 12 and July 25, 1955. They were absent on April 25, May 20, July 8, and October 17, 1955, and December 23, 1954. The house wells were served by pitcher pumps of the open-spout type and spouts were not sterilized before collection of samples. Under these conditions contamination of samples is not unexpected. M.P.N. of positive samples was not indicated, as they were subjected only to routine analyses for potable water. If coliform-type bacteria present at the house well had originated in lagoon seepage, samples would have remained positive after May 12. Coliform bacteria evi-

dently did not survive any such distance in the slow-flowing ground water.

Infiltration has been noted to reduce coliform concentration. The New York State Department of Health (25) considers water supply wells to be safe in sandy soil if they are located at least 100 ft. from a source of fecal

TABLE VII.—Chloride and Detergent[1] in Ground Water (P.P.M.)[2]

Test Location	Jul. 19, 1954		Jul. 28, 1954		Aug. 2, 1954		Oct. 6, 1954		Oct. 19, 1954	
	Chl.[3]	Det.[4]	Chl.[3]	Det.[4]	Chl.[3]	Det.[4]	Chl.[3]	Det.[4]	Chl.[3]	Det.[4]
Sand Point 1	79.8	4.4	80.7	5.6	85.5	4.8	—	—	—	—
Sand Point 2	76.9	3.2	79.8	2.1	79.8	5.4	—	—	—	—
Sand Point 3	78.8	4.0	79.8	4.8	81.7	7.4	81.8	8.0	85.5	8.0
Sand Point 4	—	—	—	—	—	—	46.5	1.0	46.5	1.0
Sand Point 5	—	—	—	—	—	—	22.3	0.0	20.0	0.0
Sand Point 6	—	—	—	—	—	—	—	—	20.4	0.0
Sand Point 7	—	—	—	—	—	—	—	—	24.1	0.0
Sand Point 8	—	—	—	—	—	—	—	—	22.3	0.0
Sand Point 9	—	—	—	—	—	—	—	—	23.2	0.0
Sand Point 10	—	—	—	—	—	—	—	—	21.3	0.0
Sand Point 11	—	—	—	—	—	—	—	—	79.0	4.0
Sand Pit Kappas	—	—	—	—	—	—	45.5	2.0	—	—
Crawford House Well	25.6	0	24.7	0	24.7	0	24.7[5]	0	—	—
Sand Pit—south	—	—	—	—	—	—	—	—	24.1	0.0

Test Location	Nov. 10, 1954		Jun. 10, 1955		Jun. 11-12, 1955		Jun. 13-14, 1955		Jul. 12, 1955	
	Chl.[3]	Det.[4]	Chl.[3]	Det.[4]	Chl.[3]	Det.[4]	Chl.[3]	Det.[4]	Chl.[3]	Det.[4]
Sand Point 5	—	—	47.6	1.3	—	—	—	—	—	—
Sand Point 6	20.4	0.0	21.8	0.0	—	—	—	—	—	—
Sand Point 7	—	—	52.3	6.0	—	—	—	—	—	—
Sand Point 10	20.4	0.0	19.9	0.0	20.9	0.0	—	—	—	—
Sand Point 12	—	—	—	—	23.4	0.0	—	—	—	—
Sand Point 13	—	—	—	—	22.8	0.0	—	—	—	—
Sand Point 14	—	—	—	—	83.7	8.0	—	—	—	—
Sand Point 15	—	—	—	—	99.9	10.0	—	—	—	—
Sand Point 16	—	—	—	—	26.6	0.25	—	—	—	—
Sand Point 17	—	—	—	—	26.6	0.1	—	—	—	—
Sand Point 18	—	—	—	—	21.8	0.0	—	—	—	—
Sand Pit Kappas	45.5	3.0	26.6	0.45	—	—	—	—	—	—
Steinmark Irr. Well	—	—	—	—	—	—	—	—	83.7	9.4
Steinmark Windmill Well 1	—	—	—	—	—	—	—	—	82.8	9.8
Steinmark House Well	—	—	—	—	—	—	47.6	3.6	71.4	7.5
Merryman's Irr. Well	—	—	—	—	—	—	—	—	39.0	1.45
Mercer Irr. Well 1	—	—	—	—	—	—	29.5	0.0	24.7	0.0
Mercer Irr. Well 2	—	—	—	—	—	—	—	—	30.4	0.0
Mercer Irr. Well 3	—	—	—	—	—	—	—	—	25.7	0.02
Steinmark Windmill Well 2	—	—	—	—	—	—	24.1	0.0	28.5	0.0
Sand Pit—south	25.1	—	—	—	—	—	—	—	—	—
Peterson-Holcomb Irr. 1	—	—	—	—	—	—	26.6	0.17	28.5	0.1
Notz House Well	—	—	—	—	—	—	25.7	0.02	—	—
Brooks Irrigation	—	—	—	—	—	—	35.3	0.05	—	—
Carranza 1	—	—	—	—	—	—	—	—	23.8	0.0
Carranza 2	—	—	—	—	—	—	—	—	26.6	0.0
Peterson-Holcomb Irr. 2	—	—	—	—	—	—	—	—	26.6	0.0

[1] As sodium alkyl aryl sulfonate.
[2] Analyses by Nebraska State Department of Health.
[3] Chlorides.
[4] Detergent.
[5] Aug. 16, 1954.

contamination, such as a cesspool. The safe distance between a borehole latrine and a ground water source (23) is the distance represented by eight days of ground water travel. Coliforms traveled (22) only 10 ft. from a pit privy and have been reported to travel from 1 to 232 ft. in ground water from a source of pollution. Velocity of ground water flow largely determines the distance traveled by coliforms (18). As indicated by detergent, ground water velocity was only about 6 ft. per day at the Kearney lagoon site. Therefore, eight days of travel would amount to less than 50 ft.

Ground water quality changes indicated the desirability of impermeable lagoon bottoms in regions of ground water use. It had been assumed that any discharge to the ground would pro-

TABLE VIII.—Sewage and Lagoon Coliform (1,000 M.P.N. per 100 ml.) Related to Various Operational Phases [1]

Date	Sewage	Lagoon	Reduction (%)	Conditions[2]	Sewage			Lagoon		
					Mean	Median	Mode	Mean	Median	Mode
(1954)										
Jun. 9	2,400	30	99							
14	36	3	92							
18	230	430	−87							
21	150	91	39							
Jul. 9	430	230	47							
12	91	—	—							
16	4,600	200	96							
19	11,000	430	96							
23	11,000+	11,000+	0							
26	2,400	1,500	37							
30	2,400	2,400	0	A	4,821	3,500	11,000	1,075	430	430
Aug. 6	2,400	430	82							
9	11,000+	36	99.7							
13	11,000+	930	92							
16	4,600	1,500	67							
20	11,000	430	96							
23	11,000+	430	96+							
27	1,500	150	90							
Sep. 10	4,600	110	97.6							
13	4,600	91	98							
17	1,500	150	90	B	—	—	—	—	—	—
20	11,000	140	99							
24	11,000	73	99.4	A	—	—	—	—	—	—
27	11,000+	36	99.7							
Oct. 1	11,000	2,400	78	B	—	—	—	—	—	—
4	11,000+	2,400	78+							
8	11,000+	2,400	78+							
10	11,000	4,600	58	A	8,400+	11,000	11,000+	2,170	2,665	—
15	4,600	930	80							
18	11,000+	750	93+							
28	11,000	430	96	A[3]	—	—	—	—	—	—

[1] Analyses by city of Kearney, Nebr.

[2] A = all sewage to lagoon; B = two-thirds of sewage bypassed; C = all sewage bypassed; D = one-half of sewage bypassed.

[3] After two days complete bypass.

TABLE VIII.—Sewage and Lagoon Coliform (1,000 M.P.N. per 100 ml.) Related to Various Operational Phases [1] (Continued)

Date	Sewage	Lagoon	Reduction (%)	Conditions[2]	Sewage			Lagoon		
					Mean	Median	Mode	Mean	Median	Mode
Nov. 1	11,000+	230	—	C	—	—	—	—	—	—
5	4,600	230	95							
8	11,000+	1,500	86+	B	9,400+	11,000	11,000+	1,040	1,215	1,500
12	11,000+	930	92+							
15	11,000+	1,500	86+							
26	11,000+	4,600	58+	A	—	—	—	—	—	—
Dec. 3	910	36	—	C	—	—	—	—	—	—
10	910	91	90	A	—	—	—	—	—	—
16	11,000+	—	—							
23	11,000	930	—	C	—	—	—	—	—	—
29	23,000	—	—							
(1955)										
Jan. 7	23,000	930	96							
13	23,000	4,600	80							
28	23,000	1,500	93							
Feb. 9	23,000	4,600	80							
16	2,100	2,400	−14	B	12,311	15,000	23,000	2,976	1,500	4,600
25	15,000	930	94							
Mar. 10	360	430	−19							
17	910	390	57							
25	430	11,000	−456							
Apr. 1	2,300	2,400	−4	D	—	—	—	—	—	—
7	15,000	4,600	69							
13	9,300	4,600	51							
21	24,000	2,400	90							
27	9,300	2,400	74	B	19,556	15,000	9,300	2,099	2,400	2,400
May 5	9,300	430	95							
13	46,000	36	99.9							
20	24,000	230	99							

[1] Analyses by city of Kearney, Nebr.

[2] A = all sewage to lagoon; B = two-thirds of sewage bypassed; C = all sewage bypassed; D = one-half of sewage bypassed.

ceed toward Kearney Canal and cause no trouble at wells to the north and east. In going northeast, ground water probably followed the course of an old river bed.

Biological Features

Coliform Bacteria

Sewage showed considerable variation in coliforms, ranging from 36,000 to 46,000,000 M.P.N. per 100 ml. Fifty-four per cent of the analyses exceeded 11,000,000; 69 per cent were 4,600,000 or above; and 81 per cent were above 1,500,000 (Table VIII). For a time, dilution ranges did not permit evaluation of concentration above 11,000,000, and M.P.N.'s listed as 11,000,000 + may have equaled the 23,000,000 to 46,000,000 range noted later. With this reservation, there ap-

pears to have been rather insignificant seasonal variation.

The lagoon, on long-term bases of various operational phases, effected a substantial reduction in the mean, mode, and generally, the median sewage M.P.N. The reduction appeared to be mainly influenced by lagoon conditions. Over the entire operating period, the lagoon reduced mean, median, and mode sewage M.P.N. by 83, 95, and 96 per cent, respectively. Reductions during various operational phases may be noted in Table VIII. Weather conditions promoting anaerobiasis were more favorable to coliform survival than were periods conducive to photosynthesis. Reduced sewage load did not result in any substantially greater coliform removal on a daily basis.

Caldwell (4) mentions rapid destruction of coliform-type bacteria shown in analyses at many oxidation ponds. He refers to Pratt (17) in suggesting that algal liberation of chlorellin may be responsible, and notes that such a bactericidal effect of algae does not interfere with stabilization of sewage organic matter. Caldwell found the oxidation pond at the Shoemaker, Calif., Naval Station had "astounding efficiency" in removing coliform bacteria. Chlorination of the lagoon effluent (dosages of 12 to 15 p.p.m.) partially killed the algae and permitted a slight increase in coliform bacteria. Parker *et al.* (15) noted a similar reduction in coliform organisms in lagoons at Melbourne, Australia.

Plankton

Plankton analyses were made from straight unconcentrated samples with densities expressed as number per milliliter. The majority of samples were composited from four locations spaced across the lagoon. During winter months they were from the effluent. Counts were carried out at a magnification of 210 diameters which did not always permit identification to genus or species, and sometimes necessitated grouping of similar forms under one heading.

Phytoplankton

Qualitative Features—Various phytoplankters noted are listed in Table IX. Predominant forms were either green algae or euglenophytes, with diatoms and blue-greens as minority groups. Thirty forms occurred during the period of record, but never more than one-third of them were present at any one time.

With only one exception, dominance was held by one of three groups—*Chlamydomonas, Micractinium,* and *Euglena. Chlamydomonas* was the most numerous group following each

TABLE IX.—Phytoplankters Occurring in Kearney Lagoon over the Period May 27, 1954–May 26, 1955

Green Algae
- *Chlamydomonas* sp.
- *Carteria* sp.
- *Pandorina morum*
- *Pleodorina illinoisensis*
- *Gloeocystis gigas*
- *Gloeocystis* sp.
- *Sphaerocystis schroeteri*
- *Closteriopsis* sp.
- *Schroederia setigera*
- *Micractinium pusillum*
- *Scenedesmus dimorphus*
- *Scenedesmus arcuatus*
- *Scenedesmus quadricauda*
- *Scenedesmus* sp.
- *Oocystis natans*
- *Ankistrodesmus convolutus*
- *Coelastrum sphaericum*

Euglenophyta
- *Euglena proxima*
- *Euglena viridis*
- *Euglena oxyuris*[1]
- *Euglena spirogyra*[1]
- *Phacus torta*
- *Phacus* sp.

Diatoms
- *Hantzschia amphioxys*
- *Nitzschia amphibia*
- *Nitzschia commutata*[1]

Blue-Green Algae
- *Oscillatoria* sp.
- *Phormidium* sp.
- *Lyngbya* sp.
- *Aphanizomenon flos-aquae*

[1] Rare.

period of algal decline when anaerobic conditions became established. It was the first group to appear at the start of lagoon operation; and in the spring of 1955 it re-established aerobic conditions. *Micractinium*, while present during anaerobic periods, seemingly was able to attain maximum development only after *Chlamydomonas* had initiated return of an aerobic state. *Euglena* appeared in considerable number in midsummer and replaced *Micractinium* as the dominant form in September and October 1954. It occurred sparingly during winter months, but attained a rather dense development in May 1955.

Changes in dominant organisms in many respects appeared to follow a pattern of seasonal succession; yet, the almost unfailing appearance of *Chlamydomonas* after each anaerobic period showed that lagoon conditions also played a major role. In this lagoon, *Chlamydomonas* seemed to colonize the anaerobic sewage-laden medium and transform it into a situation favorable to development of other phytoplankters.

Quantitative Features — Maximum densities noted were slightly greater than 1,000,000 organisms per milliliter (Figure 6). This concentration was attained only by *Chlamydomonas* and *Micractinium*. On a volumetric basis one *Chlamydomonas* cell was equal to approximately 10 cells of *Micractinium*, and one *Euglena* was equivalent to about 100 *Micractinia*. However, the validity of reducing concentrations to mass per volume appears questionable, since algal influences on sewage may possibly best be measured in terms of physiological activity, in which respect a *Chlamydomonas* individual may possibly be equal or superior to an *Euglena*.

Phytoplankton densities near the maximum level were noted only during clear weather conditions in summer. Changes in concentration proceeded at a very rapid rate, and it is possible that density was at times in spring and fall greater than indicated by analyses. Higher general levels characterized the summer months, a season which must be considered most suitable to algal growth. Ice cover conditions were least favorable and permitted complete disappearance of algae upon three occasions.

The sharp, rapid fluctuations in algal density during the June to September period, when all sewage entered the lagoon, were apparently occasioned by climatological changes—periods of overcast seemingly causing a fast decline and clear weather permitting rapid increase. Field weather observations, limited to collection dates, offer no information on intervening days when the weather was frequently involved in certain observed lagoon conditions. The Kearney weather station gathers only precipitation and temperature data, and sky cover records at Grand Island and North Platte offer contradictions to observations at Kearney that could result from varying interpretations by different observers. The regional office of the U. S. Weather Bureau advised that solar radiation data collected at Lincoln, Nebr., could be used as a measure of light intensity at Kearney, provided no attempt was made to correlate conditions on anything less than a 48-hr. basis. The annual pattern at Lincoln, with slight variation in dates, may be considered reasonably representative of that at Kearney.

Solar radiation-plankton density relationships (Figure 6), with allowance for probable time variation in light intensity between Lincoln and Kearney, indicate dependence of phytoplankton upon solar radiation during the period June-September 15, 1954, when waste load was constant and temperature variation of little consequence to algae then present. Solar radiation in excess of 600 langleys appeared necessary for maximum plank-

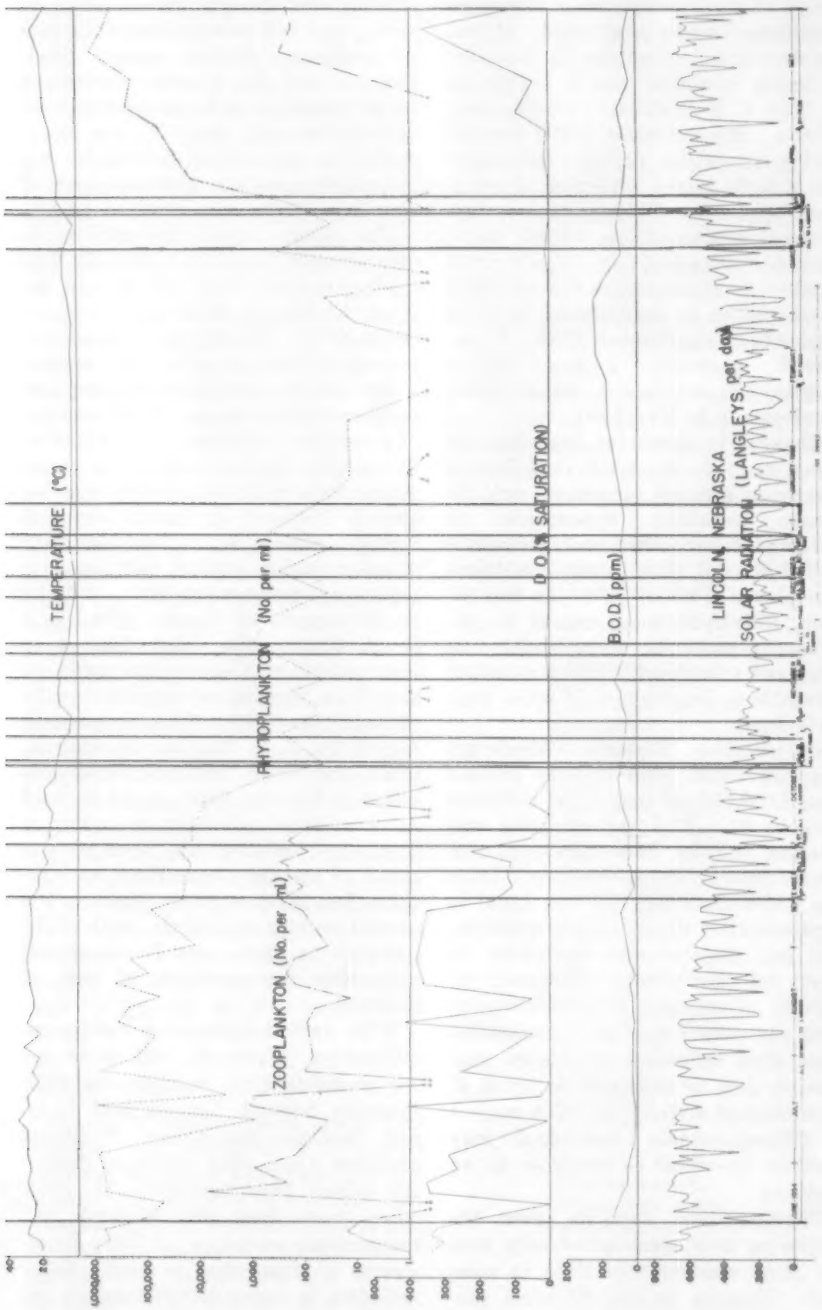

FIGURE 6.—Lagoon temperature, plankton, oxygen, B.O.D., and solar radiation variation.

ton development. However, decline in langleys seemingly induced plankton decreases, even if light intensity dropped only from 700 + to 600 + langleys. This relationship suggests that phytoplankton increases to the maximum permitted by environmental conditions and quickly declines when an unfavorable change in one factor brings productivity potential to a lower level. Light variation should not be held responsible for all plankton changes, since variation in temperature and other factors had effect on an annual basis. It seems that with optimum thermal and chemical features plankton development varied within limits imposed by available radiant energy.

Phytoplankton and Oxygen Concentration—Oxygen concentration is related to phytoplankton density and solar radiation in Figure 6. Greatest oxygen concentration, while occurring during seasons of greatest plankton growth and light intensity, was not always directly associated with plankton or solar radiation maximums. This relationship indicates that available free oxygen is not directly a measure of oxygen production, but more likely an indication of the oxygen production-consumption-loss ratio. For this reason, it is a reasonable assumption that oxygen was produced at all times when algae were present. Free oxygen was available only when production exceeded immediate demands. Greatest algal densities probably produced the largest quantities of oxygen, but also apparently provided a greater oxygen demand than did concentrations amounting to about one-half of the observed maximums.

Plankton density required to produce free oxygen varied with season and condition of the phytoplankton population. On March 17, 1955, 303 organisms per milliliter gave a 10 per cent oxygen saturation; and on November 26, 1954, 958 organisms per milliliter effected an 8 per cent saturation; yet a density of 14,616 produced no free oxygen on April 7, 1955; and an algal concentration above 50,000 per milliliter was associated with a zero oxygen value on June 18, 1954. On November 26 and March 17, low temperature, by reducing metabolic processes, allowed production of an oxygen surplus by the sparse phytoplankton populations. During warmer months of 1954, zero oxygen values apparently occurred when declines in solar radiation forced decreases in algal populations. Under these conditions algae either stopped oxygen production or produced insufficient quantities to satisfy the demands, which were probably increased by moribund and dead individuals. With only two exceptions (July 23, 1954, and May 20, 1955) oxygen rose when algae were rapidly proliferating and fell when they declined.

Phytoplankton and B.O.D.—Five-day B.O.D. was lowest in the lagoon during seasons of greatest plankton production and highest when algae were rare or absent during ice cover conditions (Figure 6). Some B.O.D. fluctuation in fall and winter was probably caused by varying sewage load to the lagoon, but no clear-cut trends are attributable to that factor. Phytoplankters may be expected to utilize oxygen in incubated samples and are responsible for a portion of the measured B.O.D. However, measured oxygen demand showed little tendency to vary up and down with plankton density during most seasons. As mentioned earlier, degree of oxygen utilization and loss in the lagoon is not accurately indicated by 5-day B.OD..

Variation in quantity of introduced raw sewage showed no marked effects upon the lagoon phytoplankton, the population increasing and decreasing during all loading phases. Density attained the same level with one-third of the sewage in May 1955 as it did with the entire sewage load in June 1954. The May 1955 ratio of development to sewage load is not predicted for all seasons, as 1955 spring popula-

tions may have benefited from nutrients held during winter months.

Zooplankton

Qualitative Features—Zooplankton was chiefly composed of ciliate protozoa and rotifers (Table X). Cladocera (*Moina*) occurred at irregular intervals, and nematodes and ostracods were occasional components. Numerical superiority was held by protozoa in 63 of 70 samples, and by rotifers on seven dates.

Quantitative Features—Concentration varied from 0.0 to 7,200 zooplankters per milliliter. Zooplankton developed greatest concentrations during seasons of densest phytoplankton growth, and was present in densities of less than 1 per milliliter during the greater part of fall, winter and spring (Figure 6). The lagoon plankton fauna appeared best suited to conditions promoted by algal growth, although certain components (*Moina* and *Brachionus*) became most numerous during periods of algal decline. However, these forms were not represented during seasons of extremely low phytoplankton densities.

Routine plankton samples were not always illustrative of all zooplankton growth, as dense aggregations of *Moina* frequently occupied extremely shallow areas when they were not represented in samples from deeper water.

TABLE X.—Zooplankters Occurring in Kearney Lagoon

- Protozoa
  - Ciliophora
    - *Paramecium caudatum*
    - *Paramecium putrinum*
    - *Paramecium* sp.
    - *Frontonia* sp.
    - *Colpoda* sp.
    - *Lionotus* sp.
    - *Trachelius* sp.
    - *Pleuronema coronatum*
    - *Pleuronema* sp.
    - *Halteria* sp.
    - *Euplotes eurystomus*
    - *Stylonychia* sp.
    - *Strombilidium* sp.
    - *Didinium* sp.
    - *Hastatella* sp.
    - *Opisthonecta* sp.
    - *Vorticella campanula*
  - Suctoria
    - *Sphaerophyra* sp.
  - Sarcodina
    - *Arcella vulgaris*
  - Rotifers
    - *Mytilina ventralis*
    - *Brachionus angularis*
    - *Brachionus calyciflorus*
    - *Brachionus rubens*
    - *Brachionus urceolaris*
    - *Brachionus* sp.
    - *Filinia* sp.
    - *Cephalodella* sp.
    - *Lepadella* sp.
    - *Philodina* sp.
  - Nematoda
    - *Nematoda* sp.
  - Cladocera
    - *Moina macrocopa*
  - Ostracoda
    - *Ostracoda* sp.

Bottom Organisms

The lagoon was quickly invaded by aquatic insects. On June 9, 1954, 25 days after the introduction of sewage, fully grown midge larvae and pupae (*Tendipes decorus*) and young dragonfly nymphs (*Pantala flavescens*) were collected from shallow areas along the inlet embankment. Midge larvae were next observed on July 12, and they again emerged as adults before July 16, 1954. Two more hatches left the lagoon during the summer. No larvae or pupae were found during fall and winter, but another hatch emerged May 15, 1955. All midges identified were *Tendipes decorus*. Dragonfly nymphs were found only during summer months, and it is not known that they survived winter conditions. Adults of *Pantala flavescens* and *Plathemis lydia* were observed ovipositing in the lagoon in May and July 1955, and their nymphs were present in June 1955. No other bottom-dwelling insects were found; sludge worms (Tubificidae) were never recovered from bottom materials.

During photosynthetic seasons the lagoon bottom, excepting the area near the northwest corner, was covered by a green gelatinous layer about ¼-in. thick. This layer was made up of

various algae which appeared to be in a healthy growing condition. Composition exhibited some variation but the following groups were normally present:

1. *Nitzschia* gr.
2. *Euglena proxima*
3. *Scenedesmus* sp.
4. *Scenedesmus dimorphus*
5. *Phormidium* sp.
6. *Chlorella vulgaris*
7. *Oocystis natans*
8. *Gloeocystis vesiculosa*

Aplanospores of *Chlorella* and dividing cells of *Gloeocystis* were usually abundant.

The benthic algal population disappeared with the onset of anaerobic conditions in the fall, but reappeared shortly after phytoplankton increased in April and May 1955. Its presence on the bottom was puzzling, as it appeared unlikely that light could penetrate that distance (up to 4 ft.) in heavily plankton-laden water. Some elements of the population also occurred regularly in the plankton, and sedimentation might account for their presence on the bottom. However, other benthic forms were rare plankters.

Marginal shallow areas contained bottom growths similar to those noted in deeper water, but the commonest plankters, *Chlamydomonas* and *Micractinium*, were also well represented. Marginal growths were usually dominated by *Phorimidium* and *Euglena proxima*. They also contained rotifers and protozoa, which were not found in benthic growths in deeper water areas.

Other Biological Features

The lagoon attracted various groups of adult aquatic insects, back-swimmers, water boatmen, whirligig beetles, water scavenger beetles, dytiscid beetles, water striders, and giant water bugs.

Various shore birds, terns, and Franklin's gulls visited the pond from time to time; and blue-winged teal and pied-billed grebes were present in late summer and fall. Shore birds and ducks were observed feeding upon cladoceran and chironomid aggregations near the shoreline. Food of other birds was not known, but they apparently remained on and near the lagoon for feeding purposes.

Effluent discharges, when they contained dense plankton concentrations, attracted many minnows and other small fishes to the section of stream just below. Large carp also were observed feeding upon organisms contained in lagoon effluent; however, during periods of sewage bypass they appeared in much lesser numbers and showed some liking for matter contained in the raw sewage.

Discussion

Lagoon Processes.

Maximum waste reduction was associated with photosynthesizing algae. Inasmuch as such algal processes are dependent upon light, lagoons are able to use the direct energy of solar radiation for sewage treatment. During the growing season, variation in solar radition appeared to be the major factor influencing phytoplankton growth. Over most of that period introduction of constant loads of sewage assured general uniformity of the chemical environment, and thermal variation was insufficient to significantly affect the dominant algae. Investigators of California sewage oxidation ponds, which are used for secondary treatment and do not receive raw sewage, have noted (1) that variation in intensity and duration of light do not markedly affect algal growth (*Chlorella*) in laboratory cultures unless a most favorable medium, usually a synthetic mineral solution, is provided. These data were in accord with their field measurements, as they found some heavy algal crops during winter months. Their findings are contrary to field observations and comparison of plankton densities to

solar radiation made at Kearney. It is probable that a lagoon receiving raw sewage offers a better algal medium than does a pond dealing with primary effluent. In a more favorable chemical medium, algae may be expected to vary more with changing physical features. Differences in composition of lagoon flora may also be concerned. *Chlorella* was never a dominant form at Kearney, yet it usually accounted for almost all the algal growth in the California lagoons studied by Allen (1).

Effective utilization of light at Kearney was apparently not directly dependent upon lagoon depth, as circulation generally permitted light contact with all water and suspended algae at intervals during daylight hours. Available light energy was apportioned among plankton algae as they moved in and out of the zone of light penetration. Little available light energy would appear to have been wasted, and no layers of sewage-laden water were deprived of the benefits of photosynthesis. It would appear that depth of water need not be restricted to the limit of effective light penetration during maximum phytoplankton densities as advocated by Oswald and Gotaas (14).

Algae were the principal oxygen source and photosynthesis alone produced quantities in excess of immediate demands. Absorption from the atmosphere, under conditions of a low water temperature (10° C.) and 100 per cent oxygen deficiency, could be expected to produce, according to the equation of Imhoff and Fair (8), only from 14.08 to 28.17 lb. of oxygen per acre per day. Inasmuch as the lagoon did not ripple, oxygen absorption probably did not amount to as much as the lower figure. During active photosynthetic seasons, oxygen absorption from the air was possible only during those periods when saturation dropped below 100 per cent. During periods of low photosynthetic intensity in fall and spring, absorption from the atmosphere could have satisfied only a portion of the oxygen demand. The assumptions of Oswald and Gotaas (14) that lagoons of this type depend primarily on surface reaeration with atmospheric oxygen, and that this process is accelerated by partial depletion of oxygen reserves, appear unwarranted in the light of data accumulated at Kearney.

Alkalinity and pH relationships indicated that bicarbonate was the chief source of carbon dioxide used in photosynthesis. Reduction of alkalinity during photosynthetic seasons resulted from transformation of bicarbonate into weakly soluble monocarbonate. Carbon dioxide arising from aerobic decomposition of carbonaceous compounds and plant and animal respiration reacted with monocarbonate and assisted sewage discharges in maintenance of bicarbonate supplies. However, photosynthetic use of carbon dioxide exceeded amounts contributed by all sources and reduction of sewage alkalinity was effected. The dependence of alkalinity reduction on photosynthesis was amply illustrated by bicarbonate increases during winter months (Figure 5). Absorption of atmospheric gases, as indicated by oxygen, was very low, and it appears unjustified to assume that photosynthetic demands were to any degree satisfied by carbon dioxide absorbed from the air.

Available carbon dioxide is an important factor in algal growth, and constant maintenance of adequate amounts is necessary for maximum phytoplankton growth. California investigators (1) have demonstrated that increased algal growth results when carbon dioxide is bubbled through a sewage *Chlorella* culture.

The effects of other chemical features upon lagoon floras are rather poorly understood. Nitrogen appears to be universally obtained from ammonium compounds, but algal growth

usually stops before all nitrogen has been utilized (1). In some instances in California, algal decline has appeared to result from phosphate exhaustion.

It appears from reports of California investigators (1)(19) that raw sewage lagoons offer a type of algal environment that differs markedly in some respects from that of ponds receiving primary effluents. Raw sewage lagoons, as exemplified by the one at Kearney, are not preceded by any extensive periods of anaerobiasis and may lack amino acids and other compounds considered (19) detrimental to algal growth. Introduction of raw sewage probably also provides larger and more constant quantities of various algal nutrients.

Algae do not exist in lagoons alone, but are dependent to an unknown degree on various aquatic bacteria. California investigations (1)(19) have suggested the importance of bacterial populations. Allen (1) found both sulfate-reducing bacteria and photosynthetic purple bacteria upon lagoon bottom muds. Under laboratory conditions it was determined that the alga *Chlorella* does not oxidize organic matter in sewage, and concluded that oxidation is carried out by bacteria and other non-photosynthetic organisms. In the laboratory *Chlorella* grew more luxuriantly in a sewage median seeded with bacteria than in sewage alone. Silva and Papenfuss (19) assumed that bacteria were largely responsible for breakdown of organic matter and considered algal influences on bacteria to be of the utmost importance in lagoon processes. Photosynthetic and saprophytic relationships are further complicated by the ability of certain lagoon algae to grow in the dark in the presence of organic compounds. Further study of biotic relationships is highly desirable. It seems generally agreed that B.O.D. and other waste reduction in lagoons is accomplished by tying up various compounds in plankton bodies. At Kearney, it appeared that a change in environment, which would be accomplished by effluent discharge to a stream, slowed the rate of oxygen consumption in the dark by algae and other organisms.

Performance of Kearney Lagoon

The lagoon effected waste reduction comparable to conventional secondary treatment during a greater part of the time. Decline below that percentage of B.O.D. removal was only during adverse weather conditions. With favorable weather conditions, less than 10-day retention of total sewage load gave 82 to 90 per cent B.O.D. reduction, whereas unfavorable weather produced 32 to 56 per cent B.O.D. removal from loads amounting to only one-third to one-half of the total sewage. As primary treatment is considered adequate for stream sanitation at Kearney (2), a lagoon of larger capacity would adequately handle the total sewage load. The increased volume and detention time would actually be necessary only during winter months.

The presence of detergents in ground water was the principal objectionable factor associated with the operation. Ground water could be protected by impermeabilization of lagoon bottom and sides, or by locating the lagoon in an area where infiltration would soon enter surface streams. Odors noted during anaerobic periods of operation never appeared worse than sulfide scents frequently apparent at sewage plants of conventional design.

It may be suspected in some quarters that high infiltration rate reduced quantities of sewage treated, and that the lagoon could not have accomplished the same degree of treatment without the assistance of seepage. This view is inconsistent with results of ground water analyses, which indicated, on the basis of detergent, that liquid

going into the ground received at least a comparable degree of treatment to that discharged from the lagoon. It should be borne in mind that infiltration tended to concentrate decomposable solids in the lagoon; in some respects thus actually increasing the task of the purifying processes. Also, variation in waste load during various seasons had little direct effect on B.O.D. concentration in the lagoon. It seems that a lagoon with impermeable bottom would have accomplished comparable if not better treatment, as seepage merely substituted for overflow until some sealing was accomplished.

These experiments showed that with optimum climatological features a lagoon biota can effectively treat a heavy sewage load. However, unfavorable weather conditions reduce purification capacity and, with substantial loadings, may permit development of odors and other undesirable conditions. Therefore, it would appear that design of lagoon facilities should provide loadings low enough to insure satisfactory performance during those seasons when temperature and solar radiation decline below levels necessary for maximum waste removal activities. At Kearney, the most critical seasons in this respect were late fall and early spring, as ice cover largely obviated nuisance conditions during winter.

Duration of the Kearney experiment did not allow establishment of the most desirable loading for that locality. However, it is obvious that capacity design of a lagoon should be influenced by its location and the desired level of purification. In areas fairly close to human habitations, odors as developed at Kearney would be regarded as a nuisance. In more remote localities some odor production might be entirely permissible. With the heaviest loadings used at Kearney, treatment did not decline below levels generally realized with conventional primary treatment facilities, although such purification was not realized without some odor production in fall and spring. A higher degree of purification during least favorable weather conditions would necessitate lighter loading per unit volume.

Summary

1. A 10-acre raw sewage lagoon was constructed to receive, on an experimental basis, the municipal wastes from Kearney, Nebr., which discharges about 1,637 lb. of B.O.D. per day. The lagoon was constructed in a seemingly unfavorable type of soil, and its size was considered inadequate to handle the total waste load. A cooperative investigation involving the city of Kearney, the Nebraska State Department of Health, and the Water Supply and Water Pollution Control Program of the U. S. Public Health Service was initiated to evaluate performance of a lagoon in sandy soil, adaptability of lagoon treatment to the geographical location, possible effects upon ground water, and the capacity required for adequate waste treatment.

2. Proposed operation of the lagoon was modified by high initial losses to seepage, and the study was discontinued at an earlier-than-anticipated date due to the presence of detergents in ground water. Consistent operation was obtained largely during the months when the lagoon received the total volume of sewage.

3. During seasons favorable to algal growth and when receiving the total load of sewage, the lagoon afforded B.O.D. and coliform reductions comparable to those provided by conventional secondary treatment. Decreased loading did not result in any substantial increase in percentage of waste removal. Treatment declined to the primary range during colder weather when algae were sparse or lacking.

4. Settleable solids were lacking in lagoon effluent, but lagoon turbidity, chiefly influenced by non-settling plankters, frequently greatly exceeded

that of raw sewage. Floating solids occurred to a limited extent during early phases of operation. Locally unpleasant odors developed during extended anaerobic periods. Organic bottom deposits were absent except in one small shallow area.

5. Oxygen was supplied chiefly by algal photosynthesis, and oxygen content varied with density and relative activity of plankton algae, diurnally and annually. B.O.D. reduction was most marked during sessions of algal growth. Maximum removal of B.O.D. was 173 lb. per acre per day. Average removal when receiving the total sewage load was about 128 lb. per acre per day. Loading ranged from 38 to 217 lb. of B.O.D. per acre per day.

6. Lagoon alkalinity declined below that of sewage during photosynthetic seasons, but was greater than that of sewage during fall, winter, and early spring. Purification in this respect was dependent on photosynthesis. Algal activities also reduced available nitrogen and phosphorous.

7. Lagoon seepage followed an unexpected course away from the adjacent stream and produced detergents in nearby wells. The detergent was carried about three-fourths of a mile in ground water in 14 months.

8. Coliform-type bacteria were markedly reduced during seasons of prolific algal growth. Anaerobic conditions permitted greater survival.

9. Algal growth varied on a seasonal basis, its density apparently being controlled by available solar energy. Maximum development was associated with solar radiation levels of at least 600 langleys. Zooplankton was densest during periods of greatest algal development.

10. Lagoon capacity was adequate for all sewage from the city during favorable weather conditions. Increased size would be necessary during colder seasons.

11. The principal objectionable feature associated with operation of the lagoon was the presence of detergents in ground water. Impermeabilization of the experimental lagoon or its relocation would protect ground water from seepage of this sort.

Acknowledgments

Ralph H. Lancaster, Water Superintendent, Kearney, Nebr., proposed lagoon treatment of sewage, contacted the two health agencies, and supervised construction and maintenance of the lagoon. Ray E. Lundy, City Manager, through his full interest and support, made the study possible; Rex J. Kelly, City Sanitarian, Kearney, performed routine sample collection and oxygen, B.O.D., pH, alkalinity, turbidity, settleable solids, and coliform analyses. Cooperation of the Nebraska State Department of Health was guided by T. A. Filipi, Director, Division of Sanitation, and L. O. Vose, Director of Laboratories. Special studies by that department were conducted by L. John Cooper. A stage recorder furnished through the cooperation of Douglas D. Lewis, District Engineer, Water Resources Division, U. S. Geological Survey, Lincoln, Nebr., was installed and serviced by David B. Ender, North Platte, Nebr.

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EFFECT OF VARIOUS ORGANIC SUBSTANCES ON OXYGEN ABSORPTION EFFICIENCY *

By W. Wesley Eckenfelder, Jr., Lawrence W. Raymond,† and Donald T. Lauria ‡

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Aeration involves mass transfer between two media when a driving force is created by a departure from equilibrium. The process is employed for taste and odor removal, the stripping of undesirable gaseous and organic constituents, and oxygen transfer in biological treatment processes. This paper presents preliminary studies on the effect of sewage and industrial waste constituents on the oxygen transfer mechanism. Many factors inherent to the problem are still to be evaluated.

Theoretical Considerations

In aeration processes, oxygen diffuses from air to liquid until a dynamic equilibrium is reached. In biooxidation systems, oxygen dissolved in the liquid further diffuses into the microbial cell, where it is consumed in the respiration process. Mass transfer occurs through laminar films at the gas and liquid interfaces and the turbulent body of fluid so that molecular and eddy diffusion processes will exist in series. Each of these diffusional resistances will vary with fluid turbulence.

Present methods of calculation consider the entire transfer resistance to exist in the laminar boundary layer across which molecular diffusion occurs so that it is necessary to interpret the nature of these boundary layers.

The boundary layers may be considered as hypothetical interfacial films of gas and liquid which provide a barrier to diffusion. These films exist only in a statistical sense and may be considered as a diffuse layer of varying concentration from saturation at the interface, to the bulk fluid concentration some distance from the interface. This distance or film thickness depends on fluid characteristics.

It is assumed that a dynamic equilibrium is established at the interface itself. Since no concentration buildup will occur at the interface in steady state transfer, the various diffusional resistances, (liquid and gas films) may be considered in series and the controlling rate will be that which offers the greatest resistance to diffusion. In slightly soluble gases such as oxygen, the controlling resistance occurs in the liquid film.

The rate of mass transfer may be defined as:

$$\frac{dc}{dt} = k_L \frac{A}{V} (C_s - C_L) \qquad (1)$$

where k_L is defined as the liquid film coefficient and is a function of (a) the diffusivity of oxygen in the liquid and (b) the film thickness or the rate of interfacial surface renewal. The rate of surface renewal may be interpreted as the frequency with which liquid from a solution of concentration C_L is being swept past the interface at concentration C_s. The interfacial area per unit of fluid volume is A/V. Since the interfacial area is difficult to measure, it is more convenient to

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employ an over-all coefficient k_La, where $k_La = k_L \times A/V$.

From the foregoing, it may be deduced that k_L is primarily a function of fluid turbulence and the physical and chemical factors which influence diffusivity and the surface renewal rate. The unit interfacial area (A/V) will be related to the physical nature of the aerating device and the factors which influence bubble size, the air flow rate per unit liquid volume, and the time of contact or holdup. The term k_La is a function of all the aforementioned variables. High values of k_La are indicative of efficient aeration. Detailed discussions of the mechanism have been described by Gaden (1), Danckwertz (2) and Treybal (3).

The oxygen absorption capacity of sewage and industrial wastes will vary from the capacity in pure water. The liquid-film coefficient is influenced by changes in surface tension and viscosity due to the presence of waste constituents. Reduction of surface tension reduces k_L due to the creation of a high diffusion barrier at the interface (4). In addition to this increased resistance to diffusion, Ippen and Carver (5) found reduced shear at the bubble boundary and a slower rate of bubble rise due to a smaller bubble size in the presence of a surface-active agent. This influences the rate of surface renewal. An increase in fluid viscosity will also decrease this coefficient.

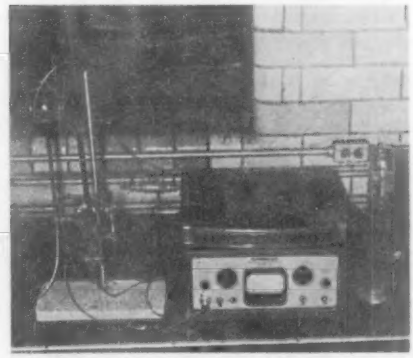

FIGURE 1.—Laboratory apparatus for oxygen absorption studies.

The interfacial area for transfer per unit volume (A/V) will also be influenced. Gaden (1) showed that it is possible for very small quantities of added surface-active agents to alter the foaming properties of the liquid sufficiently to change the effective bubble size as much as 100 times. It was shown (5) that the bubble size varied inversely with detergent concentration. Visual observations on the aeration of peptone and synthetic detergents showed a change in bubble size from large in pure water to small in water with an added constituent.

In the presence of surface-active agents, the increased diffusional resistance and lower surface renewal rate exert a greater influence on k_La than does the increase in interfacial area.

Since available data on aeration equipment performance is based on pure water at 20° C. (6), the need for evaluating the effect of specific waste constituents is evident.

Experimental Procedure

Over-all transfer coefficients were determined by non-steady state aeration under standard conditions. The transfer rate was computed from the change in oxygen concentration of the sample under aeration. The dissolved oxygen present in the sample was stripped with a nitrogen purge. Metered air was then diffused into a 1-l. sample through an aloxite diffusor stone at a specified rate. The dissolved oxygen concentration was measured at selected time intervals until the sample was approximately 90 per cent saturated.

The transfer plot was obtained for a 12-min. aeration period. The D.O. content was measured with a Sargent Manual polarograph using a dropping mercury electrode. The instrument was standardized according to the method of Seaman and Allen (7). The

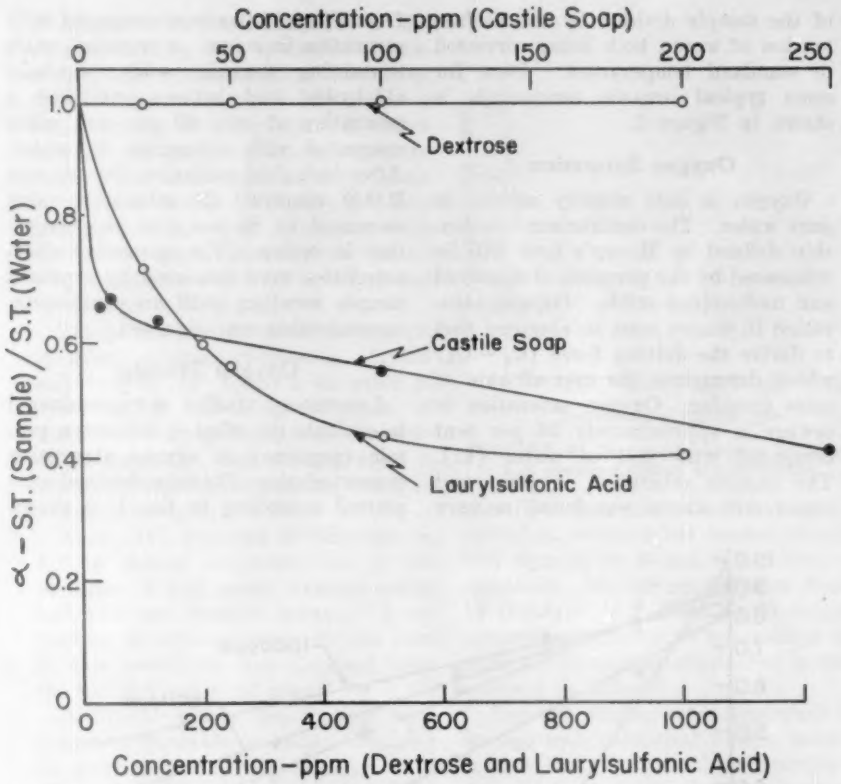

FIGURE 2.—Ratio of sample to water surface tension versus sample concentration.

experimental assembly employed is shown in Figure 1.

The non-steady state absorption of oxygen follows the exponential function shown in Eq. 1. The over-all coefficient (k_La) was computed from the slope of a plot of the saturation deficit ($C_s - C_L$) versus time of aeration.

Comparisons of the transfer coefficient of particular wastes with that of water are indicative of the relative efficiency of aeration. The oxygen absorption rate in certain wastes was compared to the rate in a 1 per cent potassium chloride solution. This solution was considered to be the equal of the pure water mentioned previously. The coefficient, k_La, at any temperature can be corrected to 20° C. using a modified Stokes-Einstein Equation (8).

The ratio of the transfer coefficients has been defined as:

$$\alpha = \frac{k_La \text{ (waste)}}{k_La \text{ (water)}} \qquad (2)$$

In the presence of activated sludge, oxygen consumption by the respiring organisms must be considered in computing k_La. The non-steady state procedure developed by Eckenfelder (9) (10) was employed to compute k_La in the presence of activated sludge.

Data on surface tension was obtained for various concentrations of the substrates, employing the platinum-ring method with a DuNouy tensiometer. It was convenient to define α as the ratio of the surface tension

of the sample divided by the surface tension of water, both being corrected to standard temperature. Data for some typical organic compounds is shown in Figure 2.

Oxygen Saturation

Oxygen is only slightly soluble in pure water. The equilibrium relationship defined by Henry's Law will be influenced by the presence of dissolved and undissolved solids. Oxygen saturation in wastes must be obtained first to derive the driving force $(C_s - C_L)$ which determines the over-all rate of mass transfer. Oxygen saturation in sewage is approximately 95 per cent compared with that of water (11). The oxygen saturation in pulp and paper mill wastes was found to vary from 77 to 97 per cent compared with saturation in water. A chemical waste containing organic acids, alcohols, aldehydes, and ketones exhibited a saturation of only 60 per cent when compared with saturation in water. After biological oxidation (90 per cent B.O.D. removal) the saturation value increased to 80 per cent the saturation in water. The saturation characteristics were measured by repeated sample aeration until an equilibrium concentration was obtained.

Oxygen Transfer

Laboratory studies were conducted to evaluate the effect of a common protein (peptone) on oxygen absorption characteristics. The data obtained were plotted according to Eq. 1 as shown

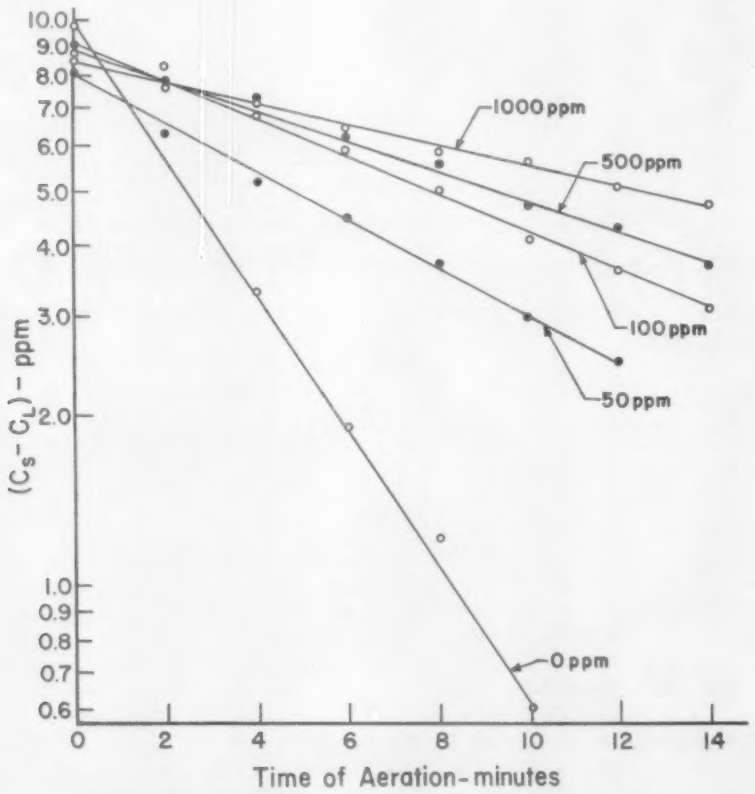

FIGURE 3.—Saturation deficit versus peptone aeration time.

in Figure 3. The coefficient α decreased rapidly with a small increase in peptone concentration, decreasing from 1.0 in water to 0.5 in a peptone concentration of 25 p.p.m. Further increases in peptone concentration to 1,000 p.p.m. reduced α to 0.2. These results are shown in Figure 4. Employing a laboratory fermentor with turbine aeration, Bartholomew *et al.* (4) found α to be 0.37 in a peptone solution of 5,000 p.p.m.

The presence of synthetic detergents in dilute solution reduces α. Lynch and Sawyer (12) found a variation in α of 0.35 to 1.10 using 50 p.p.m. of various anionic and non-ionic commercial detergents. This concentration is typical of the concentrations found in domestic sewage (5) (13).

Kehr (14) reported a reduction in k_La in stream reaeration due to the presence of oils, soaps, organic acids, and raw and treated sewage. A reduction of approximately 50 per cent in this coefficient was obtained with the use of 6 p.p.m. of soap.

Antifoam agents are finding wide usage to eliminate or reduce foaming in aeration tanks. The addition of a silicone antifoam to water reduced the oxygen absorption rate by 35 per cent. This same antifoam, when added to a chemical waste and effluent after biooxidation, reduced the oxygen absorption capacity by 20 and 35 per cent, respectively. Similar results were found by Oldshue (15). Data on the oxygen absorption capacity of water after the addition of various substances is summarized in Table I.

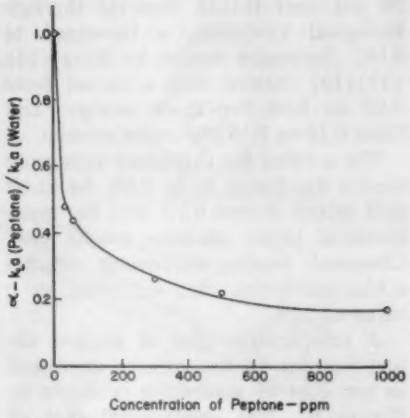

FIGURE 4.—Ratio of peptone to water k_La versus peptone concentration.

Aeration studies were conducted on sewage and industrial wastes according to the test procedure previously described. A fresh, dilute raw sewage exhibited an absorption rate of 82 per cent compared with water. After a

TABLE I.—Oxygen Absorption Capacity of Water After the Addition of Various Substances

Substance	Conc. (p.p.m.)	Temp. (° C.)	Interface Conc., C_s(%)	k_La*	α	k_La (H_2O)*
Peptone	1,000	16	92	1.25	0.172	7.28
	500	17	92	1.59	0.219	7.28
	300	16	92	1.91	0.266	7.28
	50	22	92	3.16	0.434	7.28
	25	23	92	0.58	0.480	1.20
Dextrose	1,000	20	90	1.47	0.405	3.62
	100	19	90	3.05	0.842	3.62
Silicone antifoam	—	20	91	4.19	0.67	6.26
Syndet†	50	20	97	0.56	0.439	1.275
Anionic detergent, Vel‡	50	25	—	2.35	1.10	2.13
Non-ionic detergent, Joy‡	50	25	—	1.19	0.56	2.13

* Base 10.
† Reference 5.
‡ Reference 12.

95 per cent B.O.D. removal through biological oxidation, α increased to 0.98. Extensive studies by King (16) (17) (18) showed that α varied from 0.26 to 0.46 for fresh sewage, and from 0.16 to 0.19 for septic sewage.

The α value for chipboard repulping wastes was found to be 0.60, for kraft mill mixed wastes 0.70, and for semi-chemical paper machine wastes 1.40. Chemical wastes containing organic acids, aldehydes, etc., exhibited an α value of 2.34.

A comparative plot of oxygen absorption for various wastes expressed as per cent of saturation is shown in Figure 5. The exponential plot of these data is presented in Figure 6. The temperatures of the respective curves are as shown in Table II.

Aeration studies on fermentation broths by Bartholomew *et al.* (4) indicated α values of 0.40 and 0.64 for corn steap and soybean media, respectively.

Since oxygen absorption is influenced by the presence of organic waste constituents, it may be anticipated that bio-oxidation will modify the α values to a value approaching that of water. This variation in the α value may be attributed to the chemical and physical changes which occur during the bio-oxidation process. In the

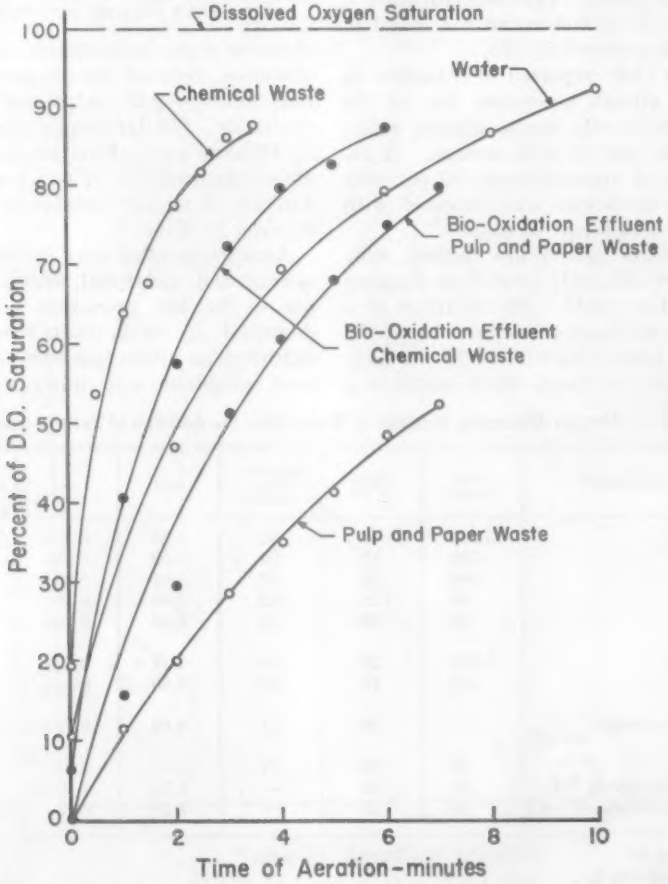

FIGURE 5.—Per cent D.O. saturation of typical wastes and water versus aeration time.

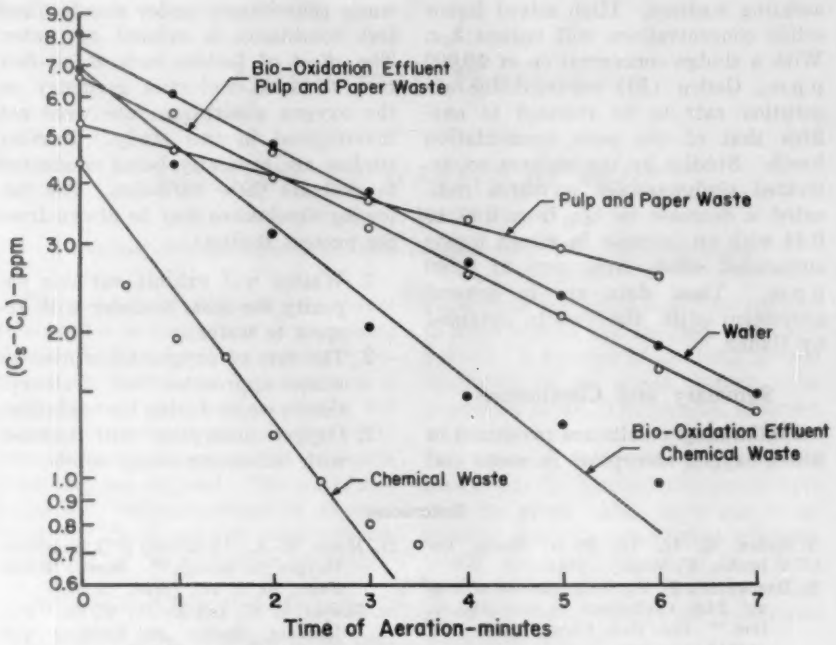

FIGURE 6.—Saturation deficit versus typical waste aeration time.

treatment of domestic sewage, 4 hr. of aeration with activated sludge increased the α value from 0.68—0.76 to 0.73—1.00. Treatment of a kraft mill waste increased the α value from 0.45 to 0.79 after 3 hr. of aeration with activated sludge. In the bio-oxidation of a chemical waste, the α value decreased from 2.34 to 1.34 with a 90 per cent reduction in B.O.D.

Observations on the aeration of sewage and organic wastes show transitions in the nature of air dispersion as the oxidation proceeds. The variation in k_La can be attributed to changes in the interfacial area per unit volume, and to changes in surface tension and viscosity.

The presence of activated sludge alters the physical properties of the

TABLE II.—Oxygen Absorption Capacity of Various Wastes

Substance	Air Flow (cu.ft./hr.)	Temp. (° C.)	Interface Conc., C_s(%)	k_La*	α	k_La (H_2O)*
Chemical waste	0.2	20	60	15.6	2.34	6.65
Chem. waste bio-oxid. eff.	0.2	18	79	8.5	1.34	6.65
Kraft mill mixed waste	0.2	36.5	96	4.6	0.70	6.6
Kraft mill bio-oxid. eff.	0.2	37	97	5.2	0.79	6.6
Chipboard repulping waste	0.1	33	77	5.5	0.68	8.1
Semi-chem. paper machine waste	0.1	36	87	11.4	1.40	8.1
Pulp and paper bio-oxid. eff.	0.1	33	90	6.2	0.77	8.1
Fresh raw sewage	0.002	17	95	3.0	0.82	3.6
Sewage bio-oxid. eff.	0.002	16	95	3.5	0.98	3.6
Sewage bio-oxid. eff.	0.002	26	90	4.3	0.63	6.9

* Base 10.

aerating medium. High mixed liquor solids concentrations will reduce k_La. With a sludge concentration of 10,000 p.p.m., Gaden (19) reported the absorption rate to be reduced to one-fifth that of the pure fermentation broth. Studies by the authors on activated sludge-sewage mixtures indicated a decrease in k_La from 0.57 to 0.44 with an increase in mixed liquor suspended solids from zero to 2,260 p.p.m. These data are in general agreement with the results obtained by Gaden.

Summary and Conclusions

Preliminary results are presented in which oxygen absorption in waste and waste constituents under standardized test conditions is related to water. The effect of factors such as air-flow rate variation and tank geometry on the oxygen absorption rate were not investigated in this study. Further studies are presently being conducted to evaluate these variables. The following conclusions may be drawn from the present studies:

1. Wastes will exhibit variable capacity for mass transfer with respect to water.
2. The rate of oxygen absorption in wastes approaches that of absorption in water during bio-oxidation.
3. Oxygen absorption will decrease with increasing sludge solids.

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Industrial Wastes

DISPOSAL OF WASTES AT SEA *

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The expense of disposing of industrial wastes to deep water at sea makes this method of handling wastes questionable. The answer is that alternate methods are either objectionable because of stream and air pollution problems or they are even more expensive than deep-sea disposal. The waste material and various methods of disposal must be given careful consideration in evaluating the method to be used.

Wastes and Disposal Methods

Typical of the problems to be considered are those associated with the processing of petrochemicals. The Shell Chemical Corp. facilities at Deer Park, Texas, process a wide range of petrochemical products from the components found in crude petroleum.

Chlorinated Hydrocarbons

Chlorine is used in the manufacture of some of these petrochemicals and small quantities of chlorinated hydrocarbons result as by-products. Frequently these products are of no use or are produced in quantities too small to refine or modify at reasonable cost. The chlorinated hydrocarbon wastes can be burned as they are accumulated. However, the products of combustion from this type of burning are obviously more objectionable than ordinary hydrocarbon smoke.

Since burning in the vicinity of the petrochemical plant was considered undesirable, it was thought that perhaps these materials could be trucked to some remote and isolated point and burned. A number of locations seemed available, on oil leases distant from populated areas. The trouble, however, was that these remote places were so far removed from the petrochemical plant, that the hauling cost would have been too great. Also, there was no assurance that the combustion products would not reach some of the farm homes in the proposed sparsely settled areas at times when wind conditions were unfavorable.

These wastes can be burned in a special incinerator unit without adding to air pollution, by use of scrubbing equipment, wherein the gases of combustion are scrubbed with water to remove the chlorides. Unfortunately the huge volume of gas to be scrubbed, in some instances as much as 4,000 cu. ft. of gases for each gallon of the wastes burned, requires that the scrubbing equipment be made very large, and with the special corrosion-resistant alloys required, very expensive.

Consideration also was given to the use of a waste disposal well, a method used successfully for the disposal of salt water in Texas oil fields and more recently at an industrial plant near Victoria, Texas. A study was made of the possibilities of this method for the disposal of these wastes. Laboratory results indicated that with proper pretreatment some of the wastes would be compatible with the salt water to be found in the sands into which it was proposed to inject the wastes.

A number of abandoned oil wells

* Presented at the 1956 Annual Meeting, Texas Water and Sewage Works Assn.; College Station, Texas; Mar. 5–9, 1956.

were located within a reasonable distance of the plant. Unfortunately, none of these wells had been cemented through the potable-water sands, which extend to depths as deep as 3,000 ft. Although salt-water sand formations, excellent for waste injection, were available at a depth of 6,500 ft., the well selected would have had to be rebuilt for waste disposal use. The cost of sealing off the potable water sands would be about as expensive as drilling a new well, and the result would not be as satisfactory as with a well designed and constructed for the purpose of waste disposal. The cost of a new well would have been approximately $100,000, and after that expenditure the results would still have been uncertain.

Caustic Wastes

Contaminated "spent" caustic soda can result from the use of caustic soda to scrub impurities from petroleum or gas streams. The caustic soda eventually becomes used up, or "spent," in this process and may often be contaminated with sulfur or phenolic compounds. Without the contamination, the soda could be easily neutralized, at a considerable cost for the acid, and discharged to the receiving stream. With the contamination, such neutralizing could cause both air and stream pollution problems. Facilities designed for the recovery of the caustic and the contaminants are feasible, but are costly enough to make deep-sea disposal an attractive alternate.

Spent caustic soda containing sulfur compounds frequently is used in the sulfate process of manufacturing paper pulp. Thus the waste disposal problem can be avoided in a satisfactory manner.

In certain paper pulp processes excess quantities of "spent cooking liquor" or "black liquor" are produced. This liquor is partly organic (wood) and partly inorganic (caustic soda). Normally the chemicals in this liquor are recovered for re-use in pulp manufacture, but if the liquor production gets out of balance with the recovery capacity, and storage is temporarily unavailable for the excess, deep-sea disposal offers a way to avoid the curtailment of paper-making operations without causing stream pollution.

Sludges

There is another problem, one which seems to be universal, and that is the ultimate disposal of sludges. These sludges are composed of materials which do not make good fill. They are either oily, or corrosive (acid or alkali), or septic, and are the filtrates or the settled solids from industrial processes or waste stream settling chambers. Incineration is an answer for the oily sludges, and the ash would make an acceptable fill material. Lime slurry sludges can be calcined and re-used. Acid sludges are sometimes burned in boilers for their fuel value, but because of the air pollution problem there is a trend towards processing them for the recovery of the chemicals which they contain.

The cost of equipment for the incineration of oily sludges, or for the calcining of lime sludges, is high, sufficiently so to warrant consideration of deep-sea disposal as a possible alternate.

Necessary Considerations

Dilution

One thing about the sea is its immensity in terms of common measure. This is especially overwhelming to a landsman on a small ship out of sight of shore, in the Gulf of Mexico. It is still awesome to the landsman at his desk in the office calculating how much water there is in a square mile of the Gulf at, say, the 400-fathom line (500 billion gallons).

A typical barge load of organic chloride wastes, would hold almost 6,000 barrels or 250,000 gal. Considering that many of these wastes are practically insoluble in water (50 p.p.m.),

each part of the organic chloride would need 20,000 parts of water to mix with in order to dissolve. When the chlorides dissolve they would become food for marine bacteria; some would hydrolyze into harmless hydrochloric acid and carbon dioxide.

It would take only 5 billion gallons of water to receive a load of 250,000 gal. of organic chlorides. That much water is contained within only one-hundreth of a square mile of the water at the 400-fathom line.

Stopping at the 400-fathom curve and pumping the waste overboard might mix it with a sufficient volume of water to put the waste into solution. This, however, would not be a certainty. It might merely sink rapidly in a relatively small conical stream and then spread out over the bottom of the sea. But if, instead, the barge kept going at top speed beyond the 400-fathom line during the entire pumping period, then with the wastes being pumped out under water in the wake of the barge the material would certainly mix with enough water to put it all into solution.

One of the things that would be in favor of the deep-sea disposal of organic chlorides is the slight solubility of these materials. The fact that the wastes are soluble up to only a few hundred parts per million would insure that no large quantities could go into solution before great dilution would have taken place.

Preliminary laboratory work indicated that the lighter fractions of some waste materials would spread out into an extremely thin film on the surface of the sea. This film, estimated at about 0.75 μ, was estimated to have a permanency of less than a day, even in quiet water (1). By judicious selection of the disposal site, with respect to distance from shore and to the speed and direction of surface currents, this film could be prevented from reaching any given area.

One of the principal arguments in favor of deep-sea disposal of the organic chloride wastes was that it seemed certain that it could be done without serious effect on marine life.

Expenses

The principal consideration against deep-sea waste disposal, along the Texas Gulf Coast, was the high estimated cost. A sea-worthy disposal barge is an expensive item, particularly one which would be suitable for both sea and channel towing. Such a barge would be a great deal more costly than a barge of the same capacity intended for only one or the other of these uses.

During the rough winter weather a barge with a capacity of 10,000 bbl. would be able to load about 1,500 tons of waste material; in the summer months about 1,700 tons. The cost of a 10,000-bbl. deep-sea disposal barge would be approximately $10 per barrel of capacity. The life expectancy should be at least 10 years. If the materials to be handled are not corrosive, this life might well be extended to 20 years. With amortization and interest, based on a 10-year life, and with insurance and similar charges, the annual fixed charges might be almost $17,000.

Maintenance costs would vary with the kind of weather encountered at sea and with the character of the materials handled. A good estimate of this cost might be $800 per trip. If few trips are made per year, the cost could increase because sea-going equipment tends to deteriorate when it is idle.

The cost for towing, based on an average time of 55 hr. per trip, would be about $2,200 for each operation. An additional expense which should be allowed for is the cost of a competent survey of the effects of the initial operation, at least for each different type of waste material.

The total cost per ton of waste transported will depend upon the frequency of the deep-sea disposal operation. This would be about $3.50 per

ton for as few as 12 trips per year. The cost per ton would be as low as $2.00 if, with better than ordinary weather, maintenance and shore scheduling, 100 trips per year were made. These costs do not include the costs for shore facilities.

Jurisdiction

Several governmental agencies or authorities are concerned with what goes on at sea, even well beyond the seaward edge of the continental shelf. Along the Texas coast, south of Galveston, this deep-sea area can be considered to be beyond the 400-fathom line, more than 110 miles south of Galveston. The continental shelf at this locale is considered to extend to the 100-fathom line, which is about 95 miles south of Galveston. It is understood that the jurisdiction of the Corps of Engineers, United States Army, extends to the edge of the continental shelf. The Corps of Engineers is particularly concerned with the protection of navigation and of course with shore works pertaining to navigation.

Near shore, out to the old accepted limits, 3 miles, 3 leagues, or 12 miles, there is little question regarding where jurisdiction lies. On the Texas coast the following agencies have jurisdiction within these limits: the Corps of Engineers with respect to navigation of coastal waters; the Texas State Department of Health and the United States Public Health Service with respect to health; the Texas Game and Fish Commission and the United States Fish and Wild Life Service, with respect to marine life; and the United States Coast Guard. These agencies of government are concerned not only with what goes on within the near shore limits but also with any operation occurring outside of these limits which would effect the waters near shore.

Beyond the continental shelf there is no well-defined jurisdiction as to the disposal of wastes. All of the agencies mentioned are keenly interested in any possible effects of waste disposal on marine life, from the point of view of the fisheries industry and the public health.

For the deep-sea waste disposal method to be successful, it is essential that the procedure can be shown to have no serious effect on marine life.

The following steps briefly summarize the procedure that should be followed prior to embarking on a program of deep-sea disposal of wastes:

1. Make a sufficient laboratory study to be certain that the waste material can be absorbed and purified by the sea in a safe manner.

2. Based on favorable laboratory results, proceed with a trial operation. Advise the interested public agencies of the plans, giving them the data which served to justify deep-sea disposal as a safe method.

3. A survey and an evaluation of the effects of the first disposal operation should be made by a competent outside scientific group experienced in oceanographic and chemical work. The results of this survey should be made available to the public agencies.

4. Establish the exact position of the barge while discharging the wastes. A continuously recording fathometer with a 0- to 600-fathom range is necessary, in addition to the tug captain's log. The record on the fathometer chart should be continuous from the start of the voyage until the return to dockside. The recording fathometer is invaluable as supporting evidence in establishing that the disposal operation has been carried on at the proper distance from shore.

Equipment

Equipment necessary for deep-sea disposal resolves into a choice between a self-propelled vessel, like an oil tanker, or a towed vessel like a tanker barge (Figure 1). While it hasn't been given much consideration, a

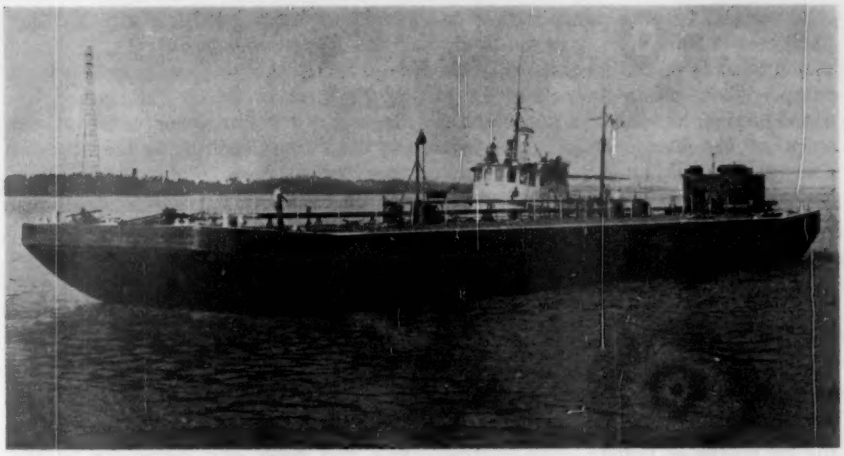

FIGURE 1.—Tanker barge for deep-sea disposal of liquid wastes.

tanker might be a strong possibility when it can be kept busy all of the time (120 to 150 trips per year). Although a tanker would be more costly than a barge, it would be capable of greater speed, and be less affected by bad weather. Accordingly, a tanker could make many more trips per year than a barge. The ability to go out in rough weather would be an advantage in that the wastes would mix and dissolve more quickly in rough water than in quiet water. Furthermore, the tanker would not depend on remote control for the pumping operations as in the case of an unmanned barge. For most cases the considerations of cost would favor a barge.

Although there are many barges traveling the intracoastal canal, there are very few barges along the Texas Gulf Coast that are suitable for the open sea. Sea-going barges must be stronger structurally to withstand the buffeting of the waves, and guiding vanes or "skegs" must be provided on the underside to keep the barge tracking straight behind the tug instead of yawing dangerously from side to side.

One typical deep-sea disposal barge has a rated capacity of 7,500 bbl. or 1,150 tons in the rough weather winter months and 1,300 tons in the summer months. With material heavier than fresh water, weight is the limit rather than volume since 1,300 tons of fresh water would approximately equal the weight of 7,500 bbl. of fresh water. Few materials lighter than sea water are suitable for deep-sea disposal.

Besides the sealed compartments or "rakes" provided for buoyancy in the tapered ends, the barge has six compartments for the cargo, two rows longitudinally with three compartments in each row. A loading manifold for pumping the liquid material into any or all of the compartments from shore tanks is provided. On the bottom of each compartment is a set of spring-closed check valves which open only to permit flow out of the tank when there is a reduction of pressure on the discharge side of the valve. These valves open into a suction trough that extends under all the valves and to a pump sump at the stern of the barge. The valves open when the action of the pump removes the waste from the trough. These compartments and valves are necessary to control the trim of the barge and to keep the liquid from flowing from one side or end of the barge to the other.

A vertical turbine pump with a capacity of 2,200 g.p.m. against a dynamic head of 33 ft. is provided in the sump. This pump is driven by a diesel engine, located in a house at the stern of the barge. The pump discharges through an 8-in. pipe which ends 12 ft. below the deck level of the barge. In practice 4 hr. are required to pump out the cargo. Pumping is continued two more hours to insure complete removal of all of the material. Chokes are provided in the pump suction and discharge to reduce the actual pumping rate to about 1,000 g.p.m. The barge is not manned and the pump can be started and stopped from the tug by means of remote radio control.

A sea-going barge requires a sea-going tug for towing purposes. There are not many sea-going tugs along the Gulf Coast capable of handling such a barge. The requirements are plenty of experienced seamanship, plenty of horsepower, plenty of freeboard and plenty of space on deck for the 1,200 ft. of 10-in. hawser that is used for the tow job.

Careful examination of certain of the properties of the waste materials is important. If vapor pressures are high, then the barge and shore equipment must be designed to handle the pressures safely. The presence of highly volatile material might create an air pollution problem while loading the barge. Acid wastes will corrode steel and strong alkalis will cause corrosion to brass. Organic materials in acid wastes can have an inhibiting effect against corrosion. Materials from which sludges might be precipitated could cause trouble with the spring-loaded check valves.

Shell Chemical Corporation Experience

The Deer Park plant of Shell Chemical Corp. to date has discharged six barge loads (about 1,200 tons per load) of waste products at sea. The first disposal was on July 14, 1953 and apparently this was the first operation of its kind involving chlorinated hydrocarbons. Altogether three of the six discharges, each being the first disposal of a given combination of materials, were surveyed and evaluated at the disposal site.

The route of the voyage outward is from dockside at the plant, down the ship channel across Galveston Bay and out between the jetties into the Gulf of Mexico until the 400-fathom line is reached. Pumping is then started and for the next 6 hr. the tow swings in a wide loop out beyond the 600-fathom line and back, not returning to the 400-fathom line until the barge is stripped of its cargo and the pump is stopped.

The reason for going out to the 400-fathom line is that the distances are such that the surface currents would not bring the film of the lighter waste materials in near any fishing grounds before the material has been completely dissipated or destroyed. Also, the steep outward slope of the continental shelf prevents the return shoreward of any of the materials which might sink to the bottom of the Gulf of Mexico.

At present there is no equipment available along the Gulf Coast for the deep-sea disposal of sludges.

Acknowledgment

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METAL PLATING WASTES AND SEWAGE TREATMENT *

By Donald Tarvin

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Metal plating wastes are produced in a number of cities in Ohio and elsewhere and may be present in the municipal sewage. The effect of metal plating wastes on biological sewage treatment is important and worthy of investigation. Various workers have reported on the toxicity of metal plating wastes to sludge digestion, and to sewage treatment processes using trickling filters and activated sludge. Interference with purification of sewage has been reported in some treatment plants. A comprehensive review of the literature on toxic materials has been made (1), but more information is needed on the effects of several metals on sewage treatment when present in the sewage at the same time.

Background

The constituents of plating baths and some of the waste products, which by drag-out and rinsing may be discharged to the sewer, have been given by Ehlen (3). Zinc, cadmium and copper plating may be done in alkaline baths containing complex cyanides, free cyanides and other substances, while nickel and chromium are generally plated in acid baths.

The stability of the metal cyanide complexes has been indicated by dissociation constants given by Milne (2). Of the following complex cyanides, ferrocyanide is the most stable followed by copper cyanide and nickel cyanide. Zinc and cadmium cyanides are the least stable.

Although these substances are present in plating baths and rinse waters from plating, it is not certain how long the complexes remain as such after they enter the sewer and reach the sewage treatment plant. It would be expected that the less stable complex cyanides of zinc and cadmium might be decomposed and precipitated more completely in sewage treatment plants than the more stable complex cyanides of nickel, copper and iron. Some free cyanide from the rinse water and possibly some dissociated metal ions will be present in the sewage. Copper and nickel ions, and sometimes zinc, may be present from acid baths which contain no cyanide. It appears that metal ions (not complexes) such as zinc, cadmium, copper, nickel and iron might be precipitated in sewage treatment plants as insoluble compounds. Zinc would be precipitated from zincate when the pH is lowered. Chromium is ordinarily present in the plating bath as chromic acid or hexavalent chromium, but some of this may be reduced in sewage to trivalent chromium and precipitated.

Gurnham (4) reported that trickling filter operation is affected by relatively small concentrations of the simple cyanides of sodium or potassium. At first, nitrification is inhibited by about 2 p.p.m. cyanide. However, by a slow and steady increase in cyanide concentration in the raw sewage, trickling filter tolerance can be built up to cyanide concentrations of 100 to 200 p.p.m. Trickling filters are much more severely affected by shock doses of cyanide than by gradual increases, but even shock loads can be overcome in time.

The effects of complex metal cya-

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nides on trickling filters are generally less severe than the effects of alkali metal cyanides. The stable complexes such as ferro and nickel cyanides have the least effect. Less stable complexes such as copper and cadmium are intermediate in their effect on trickling filters.

By suitable acclimatization microorganisms can be developed on trickling filters which tolerate cyanide compounds and can also destroy cyanide. At 100 mg. of cyanide per liter, 99 per cent of the cyanide in the simple potassium salt or in the complex cyanides of zinc, cadmium or copper can be destroyed by trickling filters after proper acclimatization of the filter microorganisms. Destruction of cyanide also will be less thorough with the more stable cuprocyanide and nickel cyanide complexes. Ferrocyanides will be attacked only slightly but can be oxidized to ferricyanides.

Ridenour and Greenbank (5) reported that activated sludge is affected by 2 to 3 p.p.m. of cyanide which retarded nitrification, but that it recovered readily from brief cyanide overloads of as much as 40 p.p.m., which stopped nitrification completely. Although trickling filter operation is affected adversely by cyanide concentrations of the order of 2 to 3 p.p.m., the microorganisms are more readily acclimated to toxic conditions than activated sludge organisms.

Chamberlin and Snyder (6) showed that at pH 11 practically all of the cyanide in a simple alkali cyanide, such as sodium and potassium cyanides, is present as cyanide ion. At pH 8 about 95 per cent of the cyanide is present as undissociated HCN. At pH 7 practically all of the cyanide is present as undissociated HCN. With the complex zinc cyanide in a rinse or waste water, the nature of the free cyanide, the amount of free cyanide, and the composition of the metallic cyanides are dependent upon the pH value. It appears logical that at pH values near 7, some of the cyanide in sewage should be removed by aeration of the sewage and activated sludge, depending on the amount of undissociated HCN produced from simple cyanides and complex cyanides.

The effect of toxic metal ions on oxidation of sewage was investigated by Heukelekian and Gellman (7). Using a Warburg respirometer they measured the oxygen utilization over a five-day period of sewage plus various concentrations of metals ranging from 0 to 100 p.p.m. Another study was made of the 6-hr. and 24-hr. oxygen demand of activated sludge-sewage mixtures (2,000 p.p.m. solids) with no metal ions added and in the presence of 5 to 100 p.p.m. of each of several metals. The metal salts used for this work did not contain cyanide, in contrast to the usual metallic cyanides found in metal plating wastes or rinse waters.

It was found that the order of decreasing toxicity for activated sludge-sewage mixtures was nickel, copper, trivalent chromium, cadmium, zinc, and hexavalent chromium. The toxicity of each metal ion increased as the concentration was increased, but none of the metals completely prevented oxidation by the activated sludge. The investigation was made with only one metal salt at a time and did not include the combined effect of several metallic ions which might be present in a sewage containing metal plating wastes. Nickel was found to be the most toxic of the metal ions studied. However, because of the limited supply of nickel, the cost, and other considerations, the amount of nickel discharged to sewers and present in the sewage is likely to be small and would have less effect on sewage treatment than some of the other metal ions. Copper may be present in sewage in larger amounts than nickel. Only a low concentration of copper would be tolerated by activated sludge in a sewage treatment plant. Somewhat greater concentrations of zinc and hexavalent chromium could be tolerated. Trivalent chromium probably

would precipitate and would be removed in the primary settling tanks ahead of the activated sludge unit.

Heukelekian and Gellman found that in activated sludge-sewage mixtures the retarding influence of metals on oxidation occurred after prolonged periods of oxidation rather than during the initial period. Maximum time of contact was 26 hr. Rudolfs and Zuber (8) showed that the removal of metal ions such as copper and zinc from solution by activated sludge was dependent on the time of contact.

Heukelekian and Gellman also found that in the biochemical oxidation of sewage (not activated sludge) the effect of a given toxic metal increased when the strength of the sewage decreased. Ingols (9) pointed out that the effect of toxic substances foreign to biological life becomes greater as other factors in the environment become less favorable for growth. Conversely, it appears that the effect of toxic substances on sewage treatment organisms should be minimized if optimum conditions for the organisms are maintained such as optimum temperature, adequate and available food supply, proper loading of B.O.D. to activated sludge, and proper aeration of activated sludge.

Some evidence was obtained in the studies on the oxidation of sewage that an increased tolerance to toxicity of metal ions was developed by adapting the seed to repeated additions of metal ions.

Laboratory Studies of Metal Plating Solutions and Activated Sludge

Studies were made in the laboratory to determine the effect of the simultaneous feeding of plating solutions containing chromium, copper, nickel, zinc and cyanide to mixtures of activated sludge and sewage.

Fresh activated sludge was obtained, mixed with raw sewage and divided into two equal parts. The mixture was placed in two 1-gal. jars and aerated simultaneously through a small diffuser extending to the bottom of each jar.

Plating solutions were prepared in the laboratory using the "Metal Finishing Guidebook-Directory" (10). The solutions used were:

1. Copper cyanide plating solution containing copper cyanide, sodium cyanide and sodium carbonate.
2. Zinc cyanide plating solution containing zinc cyanide, sodium cyanide and sodium hydroxide.
3. Nickel plating solution containing nickel sulfate, ammonium chloride and boric acid.
4. Chromium plating solution containing chromic acid.

The copper and zinc solutions contained copper and zinc as complex cyanide together with some free cyanide.

First Test

Plating solutions were added to the sewage and activated sludge in one jar in sufficient amounts to produce a mixture containing 1.86 p.p.m. copper, 3.34 p.p.m. zinc, 2.50 p.p.m. nickel, 6.28 p.p.m. cyanide, and 2.6 p.p.m. chromium. The other jar was used as a control.

After a 6-hr. aeration period the sewage and activated sludge in both jars was settled. The supernatant liquors were siphoned off and replaced with fresh sewage. Plating solutions were added to the same jar as before and aeration was continued overnight. On the second day the procedure was repeated except that twice as much metals and cyanide were fed. The procedure of aeration, settling of sludge, replacement with fresh aerated sewage and feeding metals to one jar was repeated on the third, fourth and fifth days. B.O.D. tests were made on the raw sewage fed and on the settled supernatant after 6 hr. of aeration on the fourth day and again after 4.5 hr. of aeration on the fifth day. All activated sludge was retained in the jars during the five days.

The concentration of metals in the supernatant was determined at the

TABLE I.—Effect of Plating Solutions on B.O.D. Removal by Activated Sludge in the Laboratory (First Test)

Day	Aeration Period (hr.)	Sewage plus Metals	Metals in Supernatant (p.p.m.)					5-Day B.O.D. (p.p.m.)		
			Cr	Cu	Ni	Zn	CN	Raw Sewage	Aerated Sewage and Activated Sludge	
									No Metals	With Metals
1	6	Fed	2.6	1.86	2.5	3.34	6.26*	—	—	—
	19	Fed	2.6	1.86	2.5	3.34	6.26	—	—	—
		Found†	2.5	1.7	2.4	0.4	—	—	—	—
2	24	Fed	5.2	7.44	5.0	6.7	12.5	—	—	—
3	18	Fed	5.2	7.44	5.0	6.7	12.5	—	—	—
		Found†	7.6	8.0	4.8	2.8	—	—	—	—
4	6	Fed	5.2	7.44	5.0	6.7	12.5	180	—	—
		Found†	—	—	—	—	—	—	14	74
	18	Fed	5.2	7.44	5.0	6.7	12.5	—	—	—
5	4½	Fed	5.2	7.44	5.0	6.7	12.5	365	—	—
		Found†	6.1	9.7	5.15	5.5	—	—	32	218

* Total cyanide (combined and free).
† Based on laboratory analyses.

end of the first, third and fifth days after the activated sludge had settled.

The results of this test are summarized in Table I. Zinc, which was mostly precipitated on the first day, gradually increased in the supernatant. The concentration of chromium and copper also increased.

The results of the B.O.D. tests show that four and five days of contact with relatively high concentrations of metals and cyanides in plating solutions greatly reduced the ability of activated sludge to remove B.O.D. from raw sewage. The B.O.D. removal was only 59 per cent on the fourth day and 40 per cent on the fifth day for the sewage and activated sludge with plating solutions added, as compared with 92 and 91 per cent removal for sewage and activated sludge without the metals added. It was also noted that after aeration the settled sewage and activated sludge containing the plating solutions was yellow and turbid. The settled sewage and activated sludge without the plating solutions was colorless and clear. It was apparent that the activated sludge had deteriorated upon contact with the metals and cyanide instead of building up resistance to them.

Second Test

The second laboratory study was made using a similar procedure to the first study except that the concentrations of the metals fed were less than in the first experiment. The solutions fed produced a mixture containing 3.0 p.p.m. chromium, 1.6 p.p.m. copper, 3.0 p.p.m. nickel, 2.0 p.p.m. zinc and 5.4 p.p.m. cyanide. The cyanide content was more than desired because it could not be kept low when copper and zinc were fed to give the desired concentration of metals.

Settled raw sewage instead of unsettled raw sewage was added to the activated sludge. Plating solutions to give the aforementioned concentration of metals and cyanide were added to one jar. The activated sludge and sewage in one jar and the activated sludge and sewage plus metals and cyanide in the other jar were aerated for periods indicated in Table II, settled and fed with sewage or sewage plus metals and cyanide. The B.O.D. of the settled supernatant was determined after aeration for 4.5 hr. on

the first day, 5 hr. on the second day and 16 hr. on the third day. At the end of the third day analyses for the metals were made on the activated sludge and the liquor to which the metals had been fed, on the supernatant from the activated sludge to which the metals had been added and on the control activated sludge and liquor to which no metals had been fed.

The results of this experiment are summarized in Table II. The results show that the presence of metals and cyanide in these various concentrations had a detrimental effect on the ability of the activated sludge to remove B.O.D. from sewage on all three days. It appears that the metals and the cyanide may have had a cumulative effect on the activated sludge as there was a greater difference in the B.O.D. of the supernatant from the two sludges on the third day than on the other two days.

Results of the analyses show that the mixed activated sludge and liquor contained more metals than the supernatant, indicating that there had been some concentration of metals in the sludge, particularly copper and zinc. This is particularly evident with zinc which precipitates quite readily. Considerable cyanide disappeared as approximately 5.4 p.p.m. were fed each time but only 1.67 p.p.m. were found on the third day after 16 hr. of aeration.

It was noted that after three days of feeding and aerating the activated sludge with metals added, this sludge had small floc particles and the supernatant after settling was yellow and turbid. The activated sludge without metals added had large flocs, the volume of sludge after settling was about twice the volume of sludge plus metals, and the supernatant was clear and colorless.

It is concluded that continued contact of activated sludge with a mixture of metals and cyanide in the concentrations indicated had a detrimental effect on the ability of the activated sludge to remove B.O.D. from sewage. The metals and cyanides also had a deleterious effect on the physical char-

TABLE II.—Effect of Plating Solutions on B.O.D. Removal by Activated Sludge in the Laboratory (Second Test)

Day	Aeration Period (hr.)	Sewage plus Metals	Metals in Supernatant (p.p.m.)					5-Day B.O.D. (p.p.m.)		
			Cr	Cu	Ni	Zn	CN	Raw Sewage	Aerated Sewage and Activated Sludge	
									No Metals	With Metals
1	0	Fed	3.0	1.6*	3.0	2.0	—	293	—	—
	0	Found‡	2.6	1.9	3.5	2.65	5.4	—	103	132
	4½	Fed	3.0	1.6	3.0	2.0	—	—	—	—
2	16	Fed	3.0	1.6	3.0	2.0	—	—†	—	—
	5	Found‡	—	—	—	—	—	—	30	56
		Fed	3.0	1.6	3.0	2.0	—	—†	—	—
3	16	Found‡	—	—	—	—	—	—	12	77
	16	Found‡	2.96	2.56	3.2	3.77	1.67	—	—	—
	16	Found‡	2.54	1.53	2.4	0.7	—	—	—	—
	16	Found‡	0.11	0.34	0.08	1.25	—	—	—	—

* The copper fed was probably about 1.6 p.p.m. based on the fact that 1.93 p.p.m. was found after the first feeding and 0.34 p.p.m. of copper was present in the activated sludge and liquor to which no metals were added.

† The B.O.D. of raw sewage fed was not determined on the second day.

‡ Based on laboratory analyses.

acteristics of the sludge and on the clarity of the treated sewage.

Metals and Cyanides in Sewage Treatment Plants

Investigations were made at the Marion, Ohio, sewage treatment plant which includes primary treatment and trickling filters, and at the Shelby, Ohio, treatment plant which includes primary treatment and activated sludge. Studies were made as to the amount of metal ions and cyanide in the sewage, the fate of metals and cyanide in the two sewage treatment plants and the relation of metals and cyanide to sewage treatment.

Marion, Ohio

The Marion, Ohio, sewage treatment plant was modernized in the summer of 1953. This plant serves a city of about 35,000 population and various industries. These include industries manufacturing various iron and steel products such as machinery, power shovels and automobile parts. There are also industries making dairy products, dog food, fertilizer, feed and oil from soy beans, and a wood preserving plant. Two of the industries were discharging metal plating wastes to the sewer at the time this study was made.

The treatment plant includes a bar screen, screenings grinder, grit chamber, oil skimmer, four preaeration tanks with grease skimmers, four primary settling tanks, trickling filters, four final tanks, two sludge digesters, sludge drying beds and a vacuum filter for dewatering digested sludge.

The raw sewage flow, when this study was made in November 1953, averaged 2.36 m.g.d. Recirculation of filter effluent through the primary tanks averaged 2.44 m.g.d with a total flow through the primary tanks and filters averaging 4.8 m.g.d. Suspended solids in the raw sewage averaged 176 p.p.m. and the 5-day B.O.D. was 289 p.p.m. during the month of November.

Considerable grease and oil had been received at this plant at times and metal plating wastes were noted in the raw sewage previous to the time this study was made. Wastes from some of the other industries also had been noted at times in the raw sewage, including wastes from the wood preserving plant (cresols, phenol, etc.).

Investigation showed that the metal plating wastes came from two industries. Industry "A" discharged a relatively small amount (5,760 g.p.d.) of variable plating waste with a fairly high concentration of cyanide, chromium, and copper, less nickel and a small amount of zinc and cadmium. Industry "B" discharged a much larger volume (438,000 g.p.d.) containing much lower concentrations of metals and cyanide than Industry "A".

Samples of sewage were obtained on five successive days from the following:

1. Raw sewage entering the plant, taken every 15 min.
2. Effluent from the primary settling tanks, taken hourly.
3. Trickling filter effluent, taken hourly.
4. Effluent from the final settling tanks taken hourly.

Samples of raw sewage were composited into 8-hr. and 24-hr. composites. Other samples were composited into 24-hr. samples. All samples were composited according to flow. Duplicate composite samples were preserved with potassium hydroxide (pH 11 or higher) for the determination of cyanide.

Table III shows the range and average concentrations of cyanide and metals found by analysis of the samples taken during five days. For 10 composite 8-hr. and 24-hr. samples of raw sewage taken during five consecutive days, the allowable limit was exceeded for cyanide in two samples, copper in one sample, and nickel in one sample. Except for one sample, the nickel content did not exceed 0.43 p.p.m. and the average was 0.37 p.p.m. All other samples contained less than

TABLE III.—Range and Average* Concentrations of Cyanide and Metals, Marion, Ohio, Sewage Treatment Plant

Sample	Determination (p.p.m.)											
	Cyanide		Chromium		Copper		Nickel		Zinc		Cadmium	
	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.
Raw sewage	1.78–0.18	0.80	1.42–0.10	0.41	1.24–0.28	0.69	14.0–0.16	1.66	0.98–0.34	0.54	0.33–0.04	0.21
Primary effl.	0.48–0.20	0.35	0.30–0.17	0.22	0.90–0.25	0.46	—	—	—	—	—	—
Filter effl.	0.28–0.10	0.18	0.28–0.05	0.18	0.79–0.23	0.40	—	—	—	—	—	—
Final effl.	0.20–0.09	0.15	0.20–0.12	0.17	0.60–0.18	0.32	—	—	—	—	—	—
Limit allowed	1		3		1		3		2		4	

* 24-hr. average.

the specified limit. The cyanide, chromium and copper contents decreased as the sewage flowed through the plant.

Table IV shows the sewage flows and parts per million of cyanide and metals found by analysis of the 24-hr. composite samples of the raw sewage, primary effluent, trickling filter effluent, and final effluent samples taken during five consecutive days. Parts per million of cyanide, copper and chromium became less as the raw sewage passed through the primary settling tanks, trickling filters and final settling tanks.

The trickling filters removed 41.7 to 55.5 per cent of the cyanide, 0.0 to 10 per cent of the chromium (except 77 per cent on the first day), and 0.0 to 25 per cent of the copper (except 62 per cent on the first day) from the primary effluent applied to the filters. This is calculated from the difference

TABLE IV.—Sewage Flows and Content of Cyanide and Metals

Day	Sample	Flow (m.g.d.)	Determination (p.p.m.)		
			Cyanide	Chromium	Copper
1	Raw sewage	2.43	0.52	0.32	1.24
	Primary effl.	4.87	0.20	0.22	0.90
	Filter effl.	4.87	0.10	0.05	0.34
	Final effl.	2.43	0.09	0.20	0.36
2	Raw sewage	2.34	1.10	0.48	0.82
	Primary effl.	4.78	0.31	0.23	0.48
	Filter effl.	4.78	0.14	0.22	0.40
	Final effl.	2.34	0.13	0.17	0.60
3	Raw sewage	2.39	1.20	0.17	0.52
	Primary effl.	4.83	0.36	0.20	0.36
	Filter effl.	4.83	0.16	0.18	0.79
	Final effl.	2.39	0.16	0.18	0.26
4	Raw sewage	2.32	0.70	0.30	0.33
	Primary effl.	4.76	0.40	0.17	0.32
	Filter effl.	4.76	0.21	0.19	0.24
	Final effl.	2.32	0.15	0.18	0.18
5	Raw sewage	2.31	0.47	0.77	0.52
	Primary effl.	4.75	0.48	0.30	0.25
	Filter effl.	4.75	0.28	0.28	0.23
	Final effl.	2.31	0.20	0.12	0.19

TABLE V.—Comparison of Cyanide and Metal Removal

Day	Cyanide				Chromium				Copper			
	Raw (p.p.m.)	Final (p.p.m.)	Removed		Raw (p.p.m.)	Final (p.p.m.)	Removed		Raw (p.p.m.)	Final (p.p.m.)	Removed	
			(p.p.m.)	(%)			(p.p.m.)	(%)			(p.p.m.)	(%)
1	0.52	0.09	0.43	82.8	0.32	0.20	0.12	37.5	1.24	0.36	0.88	71.0
2	1.10	0.13	0.97	88.3	0.48	0.17	0.31	64.6	0.82	0.60	0.22	26.8
3	1.20	0.16	1.04	86.9	0.17	0.18	0.0	0.0	0.52	0.26	0.26	50.0
4	0.70	0.15	0.55	78.5	0.30	0.18	0.12	40.0	0.33	0.18	0.15	45.5
5	0.47	0.20	0.27	57.5	0.77	0.12	0.65	84.4	0.52	0.19	0.33	63.5
Avg.	0.80	0.15	0.65	81.5	0.41	0.17	0.24	58.5	0.69	0.32	0.37	53.6

in parts per million between the primary effluent and the filter effluent.

Table V compares the concentrations of cyanide, chromium, and copper in the raw sewage and final effluent. The amount of cyanide and metals removed from the raw sewage and the per cent removal for each day are also shown. Removals from the raw sewage were: 57.5 to 88.3 per cent of the cyanide, 0.0 to 84.4 per cent of the chromium, and 26.8 to 71.0 per cent of the copper.

Table VI shows the five-day average concentration of cyanide, chromium and copper in the raw sewage, primary effluent, primary influent, filter effluent and final effluent. Approximately 2.44 m.g.d. of filter effluent and final tank underflow were recirculated through the primary tanks and filters in addition to 2.36 m.g.d. of raw sewage. The dilution of raw sewage with the filter effluent decreased the amount of cyanide and metals in the primary influent, but the amount of metals applied to the primary tanks was increased by the amount returned in the filter effluent.

Removal by the primary tanks was 20.8 to 30.0 per cent, removal by the trickling filters was 13.0 to 48.6 per cent. The over-all average removal in the plant was 81.5 per cent of the cyanide, 58.3 per cent of the chromium, and 53.6 per cent of the copper. It should be noted, however, that the removal varied considerably from day to day so that the daily removals shown in Table V give a somewhat better indication of removal than is shown by the values for average removal in Table VII.

Shelby, Ohio

The relation of metals and cyanide to sewage treatment in the activated sludge plant at Shelby, Ohio, also was studied. Operation of this sewage treatment plant was started during the summer of 1953. The plant receives

TABLE VI.—Average Concentration of Cyanide, Chromium and Copper

Sample	Flow (m.g.d.)	Concentration					
		Cyanide		Chromium		Copper	
		(p.p.m.)	(lb./day)	(p.p.m.)	(lb./day)	(p.p.m.)	(lb./day)
Raw sewage	2.36	0.80	15.7	0.41	8.0	0.69	13.5
Primary infl.	4.80	—	20.0	—	12.0	—	23.24
Primary effl.	4.80	0.35	14.0	0.22	8.8	0.46	18.4
Filter effl.	4.80	0.18	7.2	0.18	7.36	0.40	16.0
Final effl.	2.36	0.15	2.9	0.17	3.34	0.32	6.26
Recirculated	2.44	—	4.3	—	4.0	—	9.74

TABLE VII.—Average Daily Removal of Cyanide, Chromium and Copper

Sample	Removal					
	Cyanide		Chromium		Copper	
	(lb./day)	(%)	(lb./day)	(%)	(lb./day)	(%)
Primary infl. to primary effl.	6.0	30.0	3.22	26.8	4.84	20.8
Primary effl. to filter effl.	6.8	48.6	1.44	16.4	2.40	13.0
Raw sewage to final effl.	12.8	81.5	4.66	58.3	7.24	53.6

domestic sewage from a city of about 8,500 people, together with industrial wastes from metal working industries, including two plants discharging metal plating wastes to the sewer. Wastes are also received from an Air Force depot.

Analyses for metals and cyanides were made on raw sewage samples when the treatment plant was under construction. Later analyses were made on composite samples of waste from the metal plating plants discharging plating wastes to the municipal sewer. The flow of plating wastes was also obtained. These data indicated concentrations of chromium, nickel, copper, zinc and cyanide which would normally be present in the raw sewage received at the treatment plant, assuming no concentrated plating solutions were dumped into the sewer.

The 24-hr. daily flow of raw sewage and industrial wastes varied from 650,000 to 750,000 g.p.d., except in times of heavy rainfall when the flow might be as much as double these quantities due to infiltration.

The treatment plant consists of a screen chamber, comminutor, two preaeration tanks, two primary settling tanks, two activated sludge tanks, two final settling tanks, activated sludge return from the final tanks to the primary effluent, provision for reaeration of return sludge, two heated sludge digesters for primary and waste activated sludge, and sludge drying beds. Pumps, electrical controls, meters and blowers are located in two buildings, one of which houses the laboratory and office.

The treatment plant is treating about one-half the future design flow of 1.5 m.g.d. With the entire plant in operation the retention time in the various units is considerably longer than with conventional design. With one-half of the plant in operation the retention time, surface settling rate in the clarifiers, and aeration tank volume are similar to the design figures.

To determine the concentration and fate of metals and cyanides in the plant, composite samples were taken on three days in September 1955 when the entire plant was in operation. Samples were also taken on four days during a 30-day period in November and December, 1955, when only one-half of the plant units were used.

During the time samples were collected for metals and cyanide determinations, the mixed liquor solids in the aeration tanks averaged 2,873 p.p.m. and the return sludge was 78.7 per cent of the primary effluent flow to the aeration tanks. This was during the time the entire plant was in operation. During the period samples were taken when only one-half of the plant was used, the mixed liquor solids averaged 2,100 p.p.m. and the return sludge was 66 per cent of the raw primary effluent flow to the aeration tanks.

Samples were obtained from (a) the raw sewage entering the plant, (b) the primary settled effluent and (c) effluent from the final settling tanks. Samples were taken hourly and composited into composite 24-hr. samples

TABLE VIII.—Range of Cyanide and Metals During Partial Operation

Samples	Determination (p.p.m.)				
	Chromium	Nickel	Copper	Zinc	Cyanide
One-Half Plant					
Raw sewage	1.36–0.85	0.63–0.23	2.2–0.65	8.4–3.0	1.87–1.12
Primary effl.	1.06–0.80	0.62–0.23	1.05–0.55	4.7–2.2	1.73–0.56
Final effl.	0.60–0.45	0.33–0.18	0.72–0.35	1.6–0.42	0.42–0.16
Aeration tank	8.9–6.8	5.6–0.9	5.1–3.5	29.0–23.5	—
Entire Plant					
Raw sewage	1.07–0.51	0.38–0.05	0.69–0.17	2.65–1.08	1.90–1.16
Primary effl.	0.93–0.30	0.40–0.15	0.34–0.22	2.88–0.64	1.96–0.82
Final effl.	0.28–0.14	0.21–0.10	0.26–0.05	0.44–0.0	0.07–0.03
Aeration tanks	12.6–11.5	3.2–2.0	9.6–6.6	63.1–40.0	—

Limits specified for raw sewage:

Chromium (p.p.m.)	3.0
Nickel (p.p.m.)	3.0
Copper (p.p.m.)	1.0
Zinc (p.p.m.)	2.0
Cyanide (p.p.m.)	1.0

according to the flow. A duplicate composite sample was preserved with potassium hydroxide (pH 11 or higher) for the determination of cyanides. A sample of mixed liquor from the aeration tanks was obtained at the conclusion of each day's sampling. Analyses for metals and cyanide were made as discussed in the Appendix.

Table VIII shows the range of metals and cyanide in the raw sewage, primary effluent, final effluent and aeration tank mixed liquor, using both one-half of the plant and the entire plant.

Copper in the raw sewage exceeded the limit on one day, zinc on four days and cyanide on all seven days. The presence of 8.4 p.p.m. of zinc in the raw sewage on one day is an indication of the dumping of that industrial waste to the sewer.

Part of the metals and cyanide were removed in the primary settling tanks, with resulting lower concentrations of metals in the primary effluent going to the aeration tanks. This tends to protect the activated sludge in the aeration tanks. Further removal of metals and cyanide occurs in the aeration and final tanks with some concentration of the metals in the activated sludge mixed liquor. The final effluent discharged to the receiving stream contains considerably less metals and cyanide than the raw sewage. The sewage treatment plant, therefore protects the stream from the discharge of industrial wastes.

Table IX shows the amount of metals and cyanide found in the raw sewage, primary effluent, final effluent and mixed liquor in the aeration tanks on the four days when one-half the plant was used and on three days when the entire plant was in operation. The removal of metals and cyanide in the primary tanks is also shown. The over-all removal based on the difference in cyanide and metal content of the raw sewage and final effluent is likewise shown.

Removal of metals and cyanide in the primary tanks and the over-all removal (Table IX) are as shown in Table X.

Table X shows there was considerable variation in the removal of metals and cyanide. Average values must be interpreted with caution, but the average amount of metals and cyanide present and removed during the

TABLE IX.—Removal of Metals and Cyanide from Raw Sewage

Date	Sample	Chromium			Copper			Nickel			Zinc			Cyanide		
		(p.p.m.)	Removed		(p.p.m.)	Removed		(p.p.m.)	Removed		(p.p.m.)	Removed		(p.p.m.)	Removed	
			(p.p.m.)	(%)		(p.p.m.)	(%)		(p.p.m.)	(%)		(p.p.m.)	(%)		(p.p.m.)	(%)
		ONE-HALF PLANT														
Nov. 29	Raw sewage	0.85	—	—	2.2	—	—	0.63	—	—	3.6	—	—	1.12	—	—
	Primary effl.	0.95	—	0.0	1.05	1.15	52.3	0.62	0.01	1.6	2.2	1.4	38.9	0.56	0.56	50.0
	Final effl.	0.45	0.40	47.1	0.72	1.48	67.3	0.30	0.33	52.4	0.42	3.18	88.3	0.28	0.84	75.0
	Aeration tank	6.8	—	—	3.5	—	—	1.6	—	—	27.8	—	—	—	—	—
Dec. 1	Raw sewage	0.95	—	—	0.70	—	—	0.32	—	—	3.9	—	—	1.35	—	—
	Primary effl.	0.80	0.15	15.8	0.95	—	0.0	0.44	—	0.0	3.15	0.75	19.2	1.08	0.27	20.0
	Final effl.	0.60	0.35	36.8	0.50	0.20	28.6	0.18	0.14	43.8	0.76	3.14	80.5	0.32	1.03	76.3
	Aeration tank	8.2	—	—	4.8	—	—	5.6	—	—	27.0	—	—	—	—	—
Dec. 7	Raw sewage	1.36	—	—	0.65	—	—	0.35	—	—	3.0	—	—	1.60	—	—
	Primary effl.	1.06	0.30	22.0	0.55	0.10	15.4	0.37	—	0.0	3.3	—	0.0	1.40	0.20	12.5
	Final effl.	0.46	0.90	66.2	0.35	0.30	46.2	0.32	0.03	8.6	0.9	2.1	70.0	0.16	1.44	90.0
	Aeration tank	8.9	—	—	3.75	—	—	3.6	—	—	23.5	—	—	—	—	—
Dec. 9	Raw sewage	1.0	—	—	0.75	—	—	0.23	—	—	8.4	—	—	1.87	—	—
	Primary effl.	0.85	0.15	15.0	0.69	0.06	8.0	0.23	—	0.0	4.7	3.7	44.0	1.73	0.14	7.5
	Final effl.	0.50	0.50	50.0	0.60	0.15	20.0	0.33	—	0.0	1.6	6.8	81.0	0.42	1.45	77.5
	Aeration tank	8.2	—	—	5.1	—	—	0.9	—	—	29.0	—	—	—	—	—

TABLE IX.—Removal of Metals and Cyanide from Raw Sewage (*continued*)

Date	Sample	Chromium			Copper			Nickel			Zinc			Cyanide		
		(p.p.m.)	Removed		(p.p.m.)	Removed		(p.p.m.)	Removed		(p.p.m.)	Removed		(p.p.m.)	Removed	
			(p.p.m.)	(%)		(p.p.m.)	(%)		(p.p.m.)	(%)		(p.p.m.)	(%)		(p.p.m.)	(%)
		ENTIRE PLANT														
Sep. 19	Raw sewage	0.51	—	—	0.67	—	—	0.34	—	—	1.08	—	—	1.16	—	—
	Primary effl.	0.30	0.21	41.2	0.22	0.45	67.2	0.22	0.12	35.3	0.64	0.44	40.7	0.82	0.34	29.3
	Final effl.	0.26	0.25	49.0	0.26	0 41	61.2	0.10	0.24	70.6	0.0	1.08	100.0	0.03	1.13	97.4
	Aeration tanks	11.6	—	—	6.6	—	—	2.0	—	—	40.0	—	—	—	—	—
Sep. 21	Raw sewage	0.85	—	—	0.69	—	—	0.38	—	—	2.65	—	—	1.90	—	—
	Primary effl.	0.58	0.27	31.8	0.34	0.35	50.7	0.40	—	0.0	1.50	1.15	43.4	1.58	0.32	16.8
	Final effl.	0.14	0.71	83.5	0.05	0.64	92.8	0.21	0.17	44.7	0.44	2.21	83.4	0.05	1.85	97.4
	Aeration tanks	11.5	—	—	9.6	—	—	3.2	—	—	62.7	—	—	—	—	—
Sep. 22	Raw sewage	1.07	—	—	0.17	—	—	0.05	—	—	1.28	—	—	1.45	—	—
	Primary effl.	0.93	0.14	13.1	0.33	—	0.0	0.15	—	0.0	2.88	—	0.0	1.96	—	0.0
	Final effl.	0.28	0.79	73.8	0.19	—	0.0	0.14	—	0.0	0.40	0.88	68.8	0.07	1.38	95.2
	Aeration tanks	12.6	—	—	9.55	—	—	2.3	—	—	63.1	—	—	—	—	—

TABLE X.—Over-all Removal of Metals and Cyanide

Date	Sample	Per Cent Removal				
		Chromium	Nickel	Copper	Zinc	Cyanide
ONE-HALF PLANT						
Nov. 29–Dec. 9	Primary	22.0–0.0	1.6–0.0	52.4–0.0	44.0–0.0	50.0–7.5
	Over-all	66.2–36.9	52.4–0.0	67.3–20.0	88.3–70.0	90.0–75.0
ENTIRE PLANT						
Sep. 19–28	Primary	41.2–13.1	35.3–0.0	67.2–0.0	43.4–0.0	29.3–0.0
	Over-all	83.5–49.0	70.6–0.0	92.8–0.0	100–68.8	97.4–95.2

two surveys gives some additional information as shown in Table XI.

The average per cent removals were somewhat less using only one-half the treatment plant than when the entire plant was used. However, the cyanide and metal content (especially zinc) of the raw sewage were greater at the time one-half the plant was used so that although the percentage removal was less, more copper and zinc were removed per day using only one-half the plant. Most of the zinc and cyanide removal occurred in the aeration and final tanks.

Table XII shows the quantities of metals found in the aeration tank mixed liquor when one-half the plant, including one aeration tank, was used and when the entire plant, including both aeration tanks, was in operation.

The metal content of the mixed liquor was considerably less when one-half the treatment plant was used than during the previous study when the entire plant was in use. Conditions in the aeration tank were somewhat different, as follows:

Aeration Tanks	Per Cent Return	Mixed Liquor Solids	
		(p.p.m.)	(lb.)
Half plant	66	2,100	4,428
Entire plant	78.7	2,873	12,000

When the entire treatment plant was used (a) more solids were present in

TABLE XI.—Average Removal of Cyanide and Metals

Sampling Point	Chromium (lb.)	Nickel (lb.)	Copper (lb.)	Zinc (lb.)	Cyanide (lb.)
ONE-HALF PLANT					
Raw sewage	6.43	2.39	6.73	29.06	9.17
Primary effl.	4.67	2.59	5.03	20.56	7.34
Final effl.	3.11	1.75	3.39	5.65	1.83
Over-all removal (%)	51.6	26.8	49.6	80.6	80.0
ENTIRE PLANT					
Raw sewage	4.80	1.42	2.84	9.50	8.40
Primary effl.	3.62	1.45	1.73	10.14	4.27
Final effl.	1.34	.86	.99	1.66	0.30
Over-all removal (%)	72.1	39.4	65.2	82.5	96.4

TABLE XII.—Metals in Aeration Tank Mixed Liquor

Date	Solids (p.p.m.)	Chromium		Nickel		Copper		Zinc	
		(p.p.m.)	(lb.)	(p.p.m.)	(lb.)	(p.p.m.)	(lb.)	(p.p.m.)	(lb.)
ONE-HALF PLANT									
Nov. 30	2,070	6.8	14.3	1.6	3.4	3.5	7.4	27.8	58.5
Dec. 2	2,260	8.2	17.3	5.6	11.8	4.8	10.1	27.0	56.8
Dec. 8	2,070	8.9	18.7	3.7	7.9	3.6	7.6	23.5	49.5
Dec. 10	2,000	8.2	17.3	0.9	1.9	5.1	10.7	29.0	61.1
ENTIRE PLANT									
Sep. 20	2,960	11.6	48.9	2.0	8.4	6.6	27.8	40.0	169
Sep. 22	2,920	11.5	48.4	3.2	13.5	9.6	40.4	62.7	264
Sep. 28	2,740	12.6	53.1	2.3	9.7	9.55	40.2	63.1	266

the aeration tanks; (b) these solids generally contained a higher concentration of metals and (c) a larger quantity of the metals was present in the mixed liquor solids.

The per cent removal of suspended solids and B.O.D. during three weeks when only one-half the treatment plant was in use, and during the month of September when the entire plant was in operation, are summarized as follows:

Item	Suspended Solids Removal (%)	B.O.D. Removal (%)
ONE-HALF PLANT (Nov. 29–Dec. 21)		
Range	77.1–94.1	72.4–92.1
Usual	84.3–91.8	84.4–90.1
Avg.	86.2	86.8
ENTIRE PLANT		
Range	92.8–99.6	80.7–97.0
Usual	96.4–99	89.2–93.3
Avg.	97.6	92.0
YEAR 1955		
Avg.	92.0	92.0

Better removals of suspended solids and B.O.D. were obtained with the entire plant in operation. Considering the 92 per cent B.O.D. removal obtained during normal operation of the entire treatment plant, it appears that metals and cyanide in amounts found in the sewage did not materially affect B.O.D. removal in the plant.

The raw primary sludge and waste activated sludge are pumped to the sludge digesters. Both contain metals removed from the raw sewage which concentrate in the digested sludge. Results of analysis of a composite sample of digested sludge drawn from the secondary digester are as follows:

Analysis of Digested Sludge

Determination	Wet Basis	Dry Basis
Total solids (%)	6.73	—
Volatile matter (%)	—	46.94
Ash (%)	—	53.06
Grease (%)	—	3.7
Chromium (p.p.m.)	215	3,200
Nickel (p.p.m.)	41	610
Copper (p.p.m.)	215	3,200
Zinc (p.p.m.)	740	11,000

The metal content of the digested sludge was much higher than the metal content of the raw sewage. As in the

TABLE XIII.—Metals in Raw and Digested Sludge from Ohio Sewage Treatment Plants*

City (Ohio)	Type Plant	Plating Waste	Sludge	Samples (No.)	Solids (%)	Chromium (p.p.m.)		Copper (p.p.m.)		Nickel (p.p.m.)		Zinc (p.p.m.)		Iron (p.p.m.)	
						Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Amherst	Imhoff, filter	No	Dig.	2	9.28	3.5	38	22.8	246	—	—	—	—	1,040	11,200
Bucyrus	Activated sludge	No	Raw	3	5.33	4.3	80	14.3	269	—	—	—	—	900	16,866
			Dig.	3	4.31	3.9	90	11.5	266	—	—	—	—	1,171	27,167
Bellefontaine	Primary, filter	Yes	Raw	3	5.0	24.5	490	39.0	795	—	—	—	—	484	9,680
			Dig.	3	3.90	29.0	744	45.9	1,177	—	—	—	—	585	15,000
Columbus	Activated sludge	Yes	Raw	3	7.12	45.9	644	27.7	389	4.6	65	—	—	—	—
			Dig.	3	6.12	49.5	809	23.4	382	9.2	150	—	—	—	—
			High Rate	2	4.43	35.0	790	21.0	473	11.3	255	—	—	—	—
St. Marys	Primary, filter and activated sludge	Yes	Raw ('52)	1	—	—	—	—	611	—	—	—	4,075	—	10,540
		Yes	Dig. ('52)	1	—	—	—	—	1,185	—	—	—	6,800	—	24,165
		No	Raw ('54)	2	5.27	1.6	31	16.5	313	—	—	79.7	1,513	882	16,740
		No	Dig. ('54)	2	4.15	2.5	60	24.7	595	—	—	96.9	2,335	1,272	30,170
		No	Raw	3	4.85	7.4	153	21.0	435	—	—	—	—	1,459	30,100
		No	Dig.	3	3.83	6.9	179	15.9	414	—	—	—	—	1,227	32,150
Mansfield	Activated sludge	Yes	Raw	3	4.85	24.8	511	60.6	1,250	10.0	207	196	4,050	714	14,717
			Dig.	3	5.16	84.8	1,643	42.3	820	25.5	495	279	5,400	1,533	27,966
Marion	Primary, filter	Yes	Raw ('54)	1	6.42	80.3	1,250	31.4	490	124	1,930	82.5	1,285	680	10,680
			Dig. ('54)	2	5.64	202	3,577	65.8	1,166	177	3,030	98.0	1,740	1,810	32,100
			Dig.	1	6.87	196	2,850	72	1,050	127	1,845	—	—	2,185	31,800
Shelby	Activated sludge	Yes	Dig.	1	6.73	216	3,200	216	3,200	41	610	740	11,000	—	—

* All samples were taken in 1955 except where indicated otherwise. Results expressed as average p.p.m. of metal in wet sludge and on the basis of dry solids.

raw sewage the concentration of zinc was high and nickel was low with copper and chromium intermediate. Sludge digestion proceeded normally and no detrimental effects of these concentrations of metals on sludge digestion were observed.

Metals in Sludge From Some Ohio Sewage Treatment Plants

Analyses were made on samples of raw and digested sludges from sewage treatment plants at several Ohio cities. This was done to determine how much chromium, copper, nickel, zinc and iron were present in sludge where little or no metal plating waste was discharged to the municipal sewers, and also where considerable plating wastes were discharged. It was also desired to determine whether sufficient metals were present in the sludge to affect gas production. Results are expressed on a wet and dry basis (Table XIII).

The results for Amherst and Bucyrus, where there were no plating wastes, show low concentrations of chromium and copper in the sludge.

Bellefontaine sludge contained some chromium and copper from metal plating wastes. Columbus sludge also contained some chromium and copper and a little nickel which, apparently, came from metal plating waste.

St. Marys sludge contained considerable copper and zinc in the sludge in 1952 when a local industry discharged plating wastes to the sewer. This industry installed facilities in 1953 for treating and reducing the metal content of their waste. Samples of sludge taken during 1954 and 1955 contained less copper and zinc than found in the samples taken in 1952.

Mansfield sludge contained somewhat higher concentrations of metals than observed at St. Marys. Metal plating is done by several industries at Mansfield.

The sludge from Marion and Shelby contained higher concentrations of metals than sludges from the other cities. The discharge of metal plating wastes to the municipal sewers and its removal from the sewage at these two sewage treatment plants has been discussed previously. The sludge from both cities contained considerable chromium. The Shelby sludge contained considerable copper and a high concentration of zinc from plating waste. It has been noted that considerable zinc is generally present in sludge, and also that more iron than other metals was also present in the sludges. Iron content of the various sludges ranged from 9,680 to 32,600 p.p.m. (0.968 to 3.26 per cent). It appears that the black color of digested sludge may be caused by iron sulfide.

The relatively high nickel content of the Marion sludge is unusual as much less nickel was present in sludges from other cities. At one time considerable nickel was found in the Marion raw sewage. Some of this was pumped into the sludge digesters and was circulated with the supernatant from the digesters to the primary tanks and through the trickling filters for two or three weeks.

Metals in sludge generally reflect the discharge of metal-containing industrial waste to the sewer. No definite evidence was obtained to the effect that metals in the concentrations shown in Table XIII interfered with sludge digestion or gas production in any of these sewage treatment plants.

The treatment plant at St. Marys and the two plants with the most metals in the sludge (Marion and Shelby) produced digested sludges satisfactory for dewatering on sludge drying beds. The following data are based on yearly records:

Plant (Ohio)	Date	Sludge Solids		Volatile Matter			Gas* (cu. ft./cap./day)
		Raw (%)	Dig. (%)	Raw (%)	Dig. (%)	Reduction (%)	
St. Marys	1953	4.6	5.0	71.0	49.4	60.0	1.32
	1954	4.9	5.3	69.8	51.2	54.5	1.37
Marion	1954	5.5	7.0	71.1	54.5	51.5	1.49
	1955	5.2	8.5	72.4	51.3	60.0	1.07
Shelby	1955	6.0	8.0	72.0	46.0	67.0	1.35

* Includes gas produced from domestic sewage and industrial wastes.

Metals in Trickling Filter Slime

Metals also tend to accumulate in trickling filter slime. As shown previously at the Marion sewage treatment plant part of the copper, chromium, and cyanide in the sewage applied to the trickling filters were removed by the filters. These filters are 10 ft. deep. Analyses were made of slime scraped from stones taken from one of the filters at depths of 1, 3 and 4.5 ft. on February 19, 1954. The results of analyses are given in Table XIV. Results show considerable chromium, copper, nickel, zinc, and iron were present in the filter slime. The filters were ponded and were not operating properly at the time of this examination. Microscopic examination of the slime showed some live organisms were present but they were not abundant.

Metals and cyanide in the Marion raw sewage and in the sewage in the treatment plant on five days in November 1953 were generally below the specified limit, as shown in Tables III and IV. Samples taken on several other days during the winter and spring of 1953–54 showed similar concentrations of metals and cyanide. However "slugs" of industrial waste, especially chromium, were present in the sewage previous to and shortly after the time trouble was encountered with the filters. Nearly 12 p.p.m. of chromium were present in the raw sewage at one time on October 24, and again on December 21. On March 19 at 2:30 AM the raw sewage contained 19.0 p.p.m. chromium, 4.8 p.p.m. copper, 16.6 p.p.m. nickel, 10.5 p.p.m. zinc, 100 p.p.m. iron, and the pH was 1.4. (The filters were not in operation at the time.) It is thought that the occasional presence of relatively high concentrations of metal plating waste in the sewage and the accumulation of metals in the filter slimes were, at least partially responsible for the clogging and poorer performance of the filters. Other factors contributing to this may have been an increased load from packing house waste received during the winter, increased B.O.D. of the raw sewage and primary effluent, and the presence of some fine slag in the filter media.

Metal plating waste also was encountered at the St. Marys sewage treatment plant, as noted previously. The raw sewage flows through preaeration and primary settling tanks, a trickling filter, aeration tanks, and final settling tanks. The raw sludge and waste activated sludge from the aeration tanks go to the sludge digester. During the early winter of 1951–52, slime began to build up on the trickling filter and the surface growth became bright red in color. The filter had not been operating as efficiently as it should for some months and solids in the filter effluent increased at irregular intervals.

Samples from the sewers showed the presence of industrial waste containing copper, zinc, iron, and cyanide

from one of the local industries. During early February, samples of filter slime and other samples were taken at the St. Marys sewage treatment plant. Samples of rock were obtained from the trickling filter at the surface and at depths of 2 ft. and 4 ft. The slime was scraped off the filter media for analysis. The results of analyses of samples are shown in Table XIV.

The results show that considerable copper, zinc, and iron had accumulated in the filter slime. The metal concentration was least at the top of the filter and increased at depths of 2 and 4 ft.

The industry responsible for metal wastes at St. Marys installed a treatment plant in 1953 to remove metals from their waste before discharge to the city sewer. The effect of removal of the plating waste from the sewage could not be evaluated exactly because an increased load of organic industrial waste was received at that time from another source. The metals from plating wastes in the raw sewage accumulated in the filter slime at Marion and St. Marys and appeared to adversely affect the performance of the filters at both plants although exact proof is lacking.

When the slime on a trickling filter becomes inactive or clogs the filter, the effect may be serious, as considerable time may be required for natural cleaning of the filter media and the building of new slime. When the activated sludge becomes inactivated because of industrial wastes or other causes, it can be disposed of or reactivated by feeding and new activated sludge built up in much less time and with less complications than may be encountered with trickling filters.

Conclusions

1. Metals and cyanide in plating solutions in the concentrations used in laboratory experiments had a deleteri-

TABLE XIV.—Metals in Trickling Filter Slime

Determination	Marion, Ohio (Feb. 19, 1954)			St. Marys, Ohio (Feb. 12, 1952)*		
	Sample Depth (ft.)			Sample Depth (ft.)		
	1	3	4.5	0	2	4
Total solids (%)	19.4	13.8	9.7	8.7	10.3	11.25
Volatile solids (%)	25.6	48.7	61.2	48.6	41.3	42.1
Ash (%)	74.4	51.3	38.8	51.4	58.7	57.9
Chromium (p.p.m.):						
Wet	651	392	409	—	—	—
Dry	3,355	2,840	4,233	—	—	—
Copper (p.p.m.):						
Wet	406	292	311	49.5	223	220
Dry	2,090	2,115	3,215	523	2,150	1,950
Nickel (p.p.m.):						
Wet	326	218	161	—	—	—
Dry	1,680	1,650	1,665	—	—	—
Zinc (p.p.m.):						
Wet	146	59.5	542	204	432	500
Dry	750	425	5,600	2,339	4,180	4,540
Iron (p.p.m.):						
Wet	7,000	5,950	2,510	2,520	3,240	3,360
Dry	36,000	43,200	25,900	29,080	31,330	29,800

* Samples of raw sewage taken February 6 to 9 contained 0.6 to 1.8 p.p.m. copper, 0.7 to 1.1 p.p.m. zinc, and 1.7 to 3.0 p.p.m. iron. Sample from the sewer below the industry taken on February 7 contained 215 p.p.m. copper and 50 p.p.m. zinc, with a pH value of 1.8.

ous effect during three to five days contact with activated sludge in the laboratory. This means that indiscriminate dumping and the discharge of metal plating wastes to municipal sewers must be controlled so that detrimental concentrations of metal plating wastes do not reach the sewage treatment plant.

2. An investigation was made of the source, amount and fate of metal plating wastes at the Marion, Ohio, sewage treatment plant (primary treatment and trickling filters). Another investigation was made at the Shelby, Ohio, sewage treatment plant (primary treatment and activated sludge). This work showed that metals and cyanide in the concentrations found in samples could be tolerated by these treatment plants without materially reducing plant removal efficiency.

3. At the Marion treatment plant, part of the copper, chromium and cyanide was removed from the raw sewage in the primary settling tanks and part was removed in the trickling filters. A portion of the metals and cyanide was recirculated from the final tank through the trickling filters. There was more removal of cyanide than of copper and chromium in this plant.

4. At the Shelby treatment plant, part of the metals and cyanide was removed from the raw sewage in the primary tanks with resulting lower concentrations of metals in the primary effluent going to the aeration tanks. This tended to protect the activated sludge in the aeration tanks. Further removal of metals and cyanide occurred in the aeration and final settling tanks with some concentration of metals in the activated sludge. The final effluent discharged to the receiving stream contained considerably less cyanide and metals than the raw sewage.

5. The removal of metals and cyanide from the raw sewage varied considerably from day to day at both plants. Most of the zinc and cyanide at the Shelby treatment plant was removed in the aeration and final tanks. Because of the large amount of solids and long retention time there was a greater removal of metals and cyanide than would ordinarily occur at some other activated sludge plants.

6. Analyses for metals were made on raw and digested sludge from several Ohio sewage treatment plants. The metal content of the sludge generally reflected the discharge of metal plating wastes to the municipal sewers. No definite interference with sludge digestion by metals in the concentrations found was encountered in any of the treatment plants.

7. Analyses showed metals from plating wastes had accumulated in trickling filter slime at the Marion and St. Marys, Ohio, sewage treatment plants. It is suspected that this affected the performance of the filters at both plants for a time, although exact proof is lacking because of changing load. Activated sludge has an advantage over trickling filters in that if the sludge becomes inactivated it can be disposed of or reactivated by feeding and new activated sludge built up in much less time with less complications than may be encountered with trickling filters.

Acknowledgment

The author gratefully acknowledges the helpful suggestions and cooperation of Floyd G. Browne and John Haberman. Roy Simpson, Superintendent, Shelby, Ohio, sewage treatment plant and the late R. E. Burnett, Superintendent of the Marion, Ohio, sewage treatment plant supervised the collection of samples and supplied the data at their respective plants.

APPENDIX—DETERMINATION OF METALS AND CYANIDE

Determinations of metals in sewage and sludge were made by analytical procedures used by the Ohio Department of Health Laboratories. The earlier procedures were given by Riehl (11). Some of these were later changed or modified. Most of the procedures for determination of metals were based on the methods described by Sandell (12).

Sewage samples with the pH value adjusted to slightly greater than 9.0 with potassium hydroxide pellets were prepared for analysis by evaporation to dryness of a suitable aliquot (250 to 1,000 ml.) The dry residue was ignited in a muffle furnace at 500° to 550° C. for 2 to 3 hr. The cool residue was taken up with nitric acid followed by hydrochloric acid if necessary. The insoluble silica was filtered off and the filtrate made up to a small volume, usually 100 ml.

Sewage sludge samples to give 1 to 2 g. of dry solids were evaporated to dryness, weighed and ignited at 500° to 550° C. The ash was taken up with nitric acid and hydrochloric acid and the solution was filtered. The filtrate was made up to a final volume to give a 0.5 to 1 per cent solution (weight: volume) on the basis of the ashed residue.

Aliquots of the filtrates were evaporated to dryness and used for the determination of the metals. The residue was taken up in 0.1N hydrochloric acid except in the determination of chromium where it was taken up in sulfuric acid. Colorimetric methods were used for the determination of all metals and cyanide.

Copper was determined essentially by the procedure given by Riehl (11), using diethyl dithiocarbamate. Nickel was removed with dimethylglyoxime and centrifuged if sufficient nickel was present to interfere in the determination of copper.

Nickel was determined according to the procedure given by Riehl (11) using dimethylglyoxime, following oxidation with bromine water and the addition of ammonia to destroy the bromine color. If more than 50 pp.m. of iron are present in the original sample the first procedure given should be used instead of the second.

Zinc was determined by the procedure given by Riehl (11) using dithizone. If more than 50 p.p.m. of iron are present it is removed by preliminary extraction. Care must be used to prevent contamination with zinc from glassware and reagents. The entire procedure must be done carefully and the conditions for the several extractions required must be followed accurately.

Chromium was determined by the procedure given by Will (15). The residue after evaporation of the aliquot was taken up in dilute sulfuric acid. Silver nitrate was added to precipitate any remaining chloride. Ammonium persulfate was added and the sample was boiled for 10 min. to oxidize chromium to the hexavalent state. Chromium was determined by the colorimetric reaction with diphenyl carbazide.

Iron was determined by the thiocyanate method according to the procedure given by Will based on "Standard Methods for Examination of Water and Sewage" (13).

Cyanide was determined by the modified pyridine-benzidine reaction with cyanogen halide according to procedure of Nusbaum and Skupeko (14). Determinations were made directly on fresh samples of sewage or sewage which had been preserved by addition of potassium hydroxide to raise the pH to 11.0.

The colored solution resulting from each of the above procedures for metals and cyanide was placed in a 1-cm. cell in a Beckman Model "B" spectrophotometer. A reading was taken of the per cent transmittance or absorbance of light of a specified

wave length by each colored solution. The concentration of metal or cyanide was obtained from the spectrophotometer reading by reference to a calibration curve for known amounts of each substance. The sample reading was corrected by subtracting a blank reading obtained by following the analytical procedure using only distilled water and the reagents.

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CONTROL OF CALCIUM SULFATE SUPERSATURATION DURING LIME NEUTRALIZATION *

By W. A. Parsons and H. E. Orford

Rutgers University, New Brunswick, N. J.

Calcium sulfate supersaturation formed during lime neutralization of sulfuric acid wastes may cause deposition of scale on equipment and in effluent pipes. Previous studies (1) (2) of this phenomenon indicate that extensive supersaturation is confined to a limited acid concentration range centered at a sulfate concentration equivalent to the solubility of unstable calcium sulfate hemihydrate. These studies demonstrated that the magnitude of the supersaturation and subsequent deposition can be controlled by the addition of sufficient dosages of seed crystals in the form of return sludge or gypsum powder to the neutralized mixture, but that comparable additions to the acid solution before neutralization would be decidedly less effectual.

Analysis of these results suggested two mechanisms which possibly could be responsible for the observed phenomenon. One was the dissolution of seed crystals when added to acid solutions. Although the weight fraction dissolved would be small because of the low solubility of calcium sulfate, the percentage decrease in total surface of seed crystals conceivably could be more significant. The total surface of seed crystals added would presumably be the controlling factor in a crystal seeding process. A second possible explanation reasoned that although impurities present in the lime decreased the activity of the seed crystals in acid solutions, they were precipitated or otherwise so altered in form in neutral or alkaline solutions that less interference resulted. The initial exposure of seed crystals to a high degree of supersaturation when the seed was added to the neutralized mixture could also diminish the effects of the impurities.

Subsequent studies (3) showed that sludge dewatering properties are improved by the addition of seed crystals to the acid prior to lime neutralization. The purpose of the present investigation was to isolate factors which affect the crystal seeding process and to determine if excess dosages of seed crystals added to the acid solution prior to neutralization would compensate for reduced relative efficiency.

Laboratory Methods

Samples containing 500 ml. of an acid solution were neutralized both in the presence and absence of seed crystals (return sludge or chemically pure gypsum powder) by the addition of 10 per cent slurries of chemically pure calcium hydroxide or commercial chemical grade lime. The neutralization procedure consisted of a 5-min. mixing period with vigorous mechanical agitation to facilitate reaction between lime and acid, followed by a 1-hr. sedimentation period to separate settleable solids. The pH value of the mixture at the start of the sedimentation period was determined electrometrically to represent effluent pH. The calcium concentration of the supernatant liquid was estimated after 1 hr. of sedimentation and 24 hr. of aging, by titration of an aliquot of the effluent with disodium Versenate (4). The after-precipitation was determined as the difference between the

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

TABLE I.—Effect of Gypsum Addition on After-Precipitation Following Overneutralization of Presaturated and Unsaturated Sulfuric Acid* with High-Calcium Hydrated Lime

Variables	Test Samples						
	Control	Gypsum Added to Acid Before Neutralization				Gypsum Added to Neutralized Mixture	
Calcium sulfate, acid conc. (p.p.m.)	0	0	0	2,680	2,680	0	0
Gypsum added (p.p.m.)	0	5,000	12,000	2,320	9,320	5,000	12,000
Effluent pH	11.0	11.0	10.9	10.9	10.9	10.9	11.0
Calcium conc. at 1 hr. (p.p.m.)	2,020	1,700	1,340	1,640	1,310	1,380	1,130
Calcium conc. at 24 hr. (p.p.m.)	835	830	890	840	900	860	905
After-precipitation (p.p.m.†)	1,185	870	450	800	410	520	225
Reduction after-precipitation (%)	—	26	62	32	65	56	81

* Acid solution, 5,000 p.p.m. as calcium carbonate; acid temperature, 22° C.
† As calcium.

values obtained for the effluent calcium concentration after 1 hr. of sedimentation and after 24 hr. of aging.

Results

If acid solutions were presaturated with calcium sulfate before neutralization, it seemed reasonable to assume that any effects attributable to dissolution of seed crystals would be lessened. Table I compares the effectiveness of seed crystal additions with pure acid and acid saturated with calcium sulfate. The addition of seed crystals to the neutralized mixture was decidedly more effectual for control of after-precipitation than comparable additions to the acid solution, and presaturation of the acid did not lessen the effect.

In a second series of experiments, to determine if seed crystals were poisoned in acidic solutions by lime impurities, chemically pure calcium hydroxide was employed for neutralization. This effected approximately a 90 per cent reduction in major impurities present in chemical grade commercial lime. The experimental results (Table II) indicated that control dosages of seed crystals produced a reduction in the after-precipitation regardless of whether added to the acid solution or to the neutral mixture.

An attempt was made to evaluate possible effects attributable to major

TABLE II.—Effect of Gypsum Addition on After-Precipitation Following Overneutralization of Presaturated and Unsaturated Sulfuric Acid Solutions* with Calcium Hydroxide

Variables	Test Samples						
	Control	Gypsum Added to Acid Before Neutralization				Gypsum Added to Neutralized Mixture	
Calcium sulfate, acid conc. (p.p.m.)	0	0	0	2,680	2,680	0	0
Gypsum added (p.p.m.)	0	5,000	12,000	2,320	9,320	5,000	12,000
Effluent pH	11.5	11.1	11.1	11.1	11.2	11.2	11.1
Calcium conc. at 1 hr. (p.p.m.)	2,020	1,700	1,280	1,670	1,330	1,450	1,260
Calcium conc. at 24 hr. (p.p.m.)	1,040	865	955	890	995	1,050	945
After-precipitation (p.p.m.†)	980	835	325	780	335	400	315
Reduction after-precipitation (%)	—	15	67	20	66	59	68

* Acid solution, 5,000 p.p.m. as calcium carbonate; acid temperature, 25.5° C.
† As calcium.

impurities in commercial limes. In these experiments, compounds or combinations of compounds of aluminum, iron or silica were added to chemically pure calcium hydroxide in quantities comparable to the quantities of impurities present in commercial lime. The calcium hydroxide was then used for neutralization experiments. Data were obtained from experiments with soluble compounds of iron, aluminum, silica, silica plus aluminum and silica plus aluminum and iron. Of the simulated impurities added, only silica appeared to interfere with the ability of gypsum crystals to induce precipitation.

Most experiments, in which some form of silicate was added to the lime-acid system during or before neutralization, indicated that the presence of silicate interfered with the ability of seed crystals to induce precipitation of calcium sulfate in acid solutions. The interference, however, was not as great a magnitude as that observed in results obtained from some commercial limes. The degree of interference was apparently affected by the type of silicate employed and the method of addition, with the greatest effect observed for a tricalcium silicate addition to lime slurry. The addition of 12,000 p.p.m. gypsum to the neutralized mixture (Table III) resulted in 27 per cent less after-precipitation than a comparable addition to the acid solution before neutralization.

Results of experiments to determine if supersaturation and after-precipitation could be controlled by addition of excess dosages of seed crystals to acid solutions (Figure 1) showed that after-precipitation progressively decreased with increased dosages of seed crystals.

In experiments to determine if high dosages of return sludge would effectively control calcium sulfate supersaturation and after-precipitation from industrial wastes neutralized with commercial lime, the sulfate concentrations of industrial wastes were adjusted prior to neutralization by the addition of sulfuric acid, or by dilution, to a sulfate concentration equivalent to approximately 6,000 p.p.m. sulfuric acid. The return sludge was obtained from lime neutralization of the respective wastes with an adjusted sulfate concentration of approximately 20,000 p.p.m. The results (Table IV) showed that the after-precipitation was virtually eliminated by addition of high dosages (45,000 p.p.m.) of return sludge.

The effect of mixing time with various seed crystal dosages was also investigated. Acid solutions containing 5,000 p.p.m. acid and various dosages

TABLE III.—Effect of Addition of Tricalcium Silicate to Lime* on Control of After-Precipitation from Neutralized Sulfuric Acid† by Addition of Seed Crystals

Variables	Test Samples				
	Control	Gypsum Added to Acid Before Neutralization		Gypsum Added to Neutralized Mixture	
Gypsum added (p.p.m.)	0	5,000	12,000	5,000	12,000
Effluent pH	11.3	10.8	10.8	10.7	10.8
Calcium conc. at 1 hr. (p.p.m.)	2,030	1,950	1,600	1,620	1,410
Calcium conc. at 24 hr. (p.p.m.)	1,090	985	1,065	985	990
After-precipitation (p.p.m.‡)	940	965	535	635	420
Reduction after-precipitation (%)	—	−2.6	43	32	55

* Lime, chemically pure calcium hydroxide with 3 $CaO \cdot SiO_2$ added equivalent to 3 per cent SiO_2 in lime.

† Acid, 5,000 p.p.m. sulfuric acid; acid temperature, 22.5° C.

‡ As calcium.

TABLE IV.—Effect of Sludge Return on After-Precipitation Following Neutralization of Modified* Industrial Wastes with High-Calcium Hydrated Lime

Variables	Return Sludge† Additions					
	Calco Waste	Calco Waste	Ciba Waste	Ciba Waste	National Lead Waste	National Lead Waste
Adjusted SO_4 conc. (p.p.m.)	6,090	6,090	5,900	5,900	5,470	5,470
Adjusted total acidity (p.p.m.)	5,580	5,580	5,590	5,590	8,920	8,920
Return sludge suspended solids (g./l. acid)	0	45.2	0	46.0	0	62.0
Return sludge volume (%)	0	200	0	200	0	200
Effluent pH	9.3	9.2	9.4	9.4	7.5	7.6
Calcium conc. at 1 hr. (p.p.m.)	2,150	740	2,080	665	1,650	745
Calcium conc. at 24 hr. (p.p.m.)	1,160	725	875	655	805	720
After-precipitation (p.p.m.‡)	990	15	1,205	10	845	25
Reduction after-precipitation (%)	—	98+	—	99+	—	97+

* Sulfate concentration of wastes adjusted by addition of sulfuric acid or by dilution with water. Acid temperature, 25° C.

† Return sludge obtained by high-calcium hydrated lime neutralization of respective wastes adjusted to about 2 per cent acidity by addition of sulfuric acid.

‡ As calcium.

of chemically pure gypsum powder were neutralized to pH 10.2 with commercial high-calcium hydrated lime. At selected times during an 80-min. mixing period (200 r.p.m.), samples were withdrawn, centrifuged, and analyzed for calcium concentration. The results (Figure 2) showed that with increased dosages of seed crystals and longer mixing times, there was a

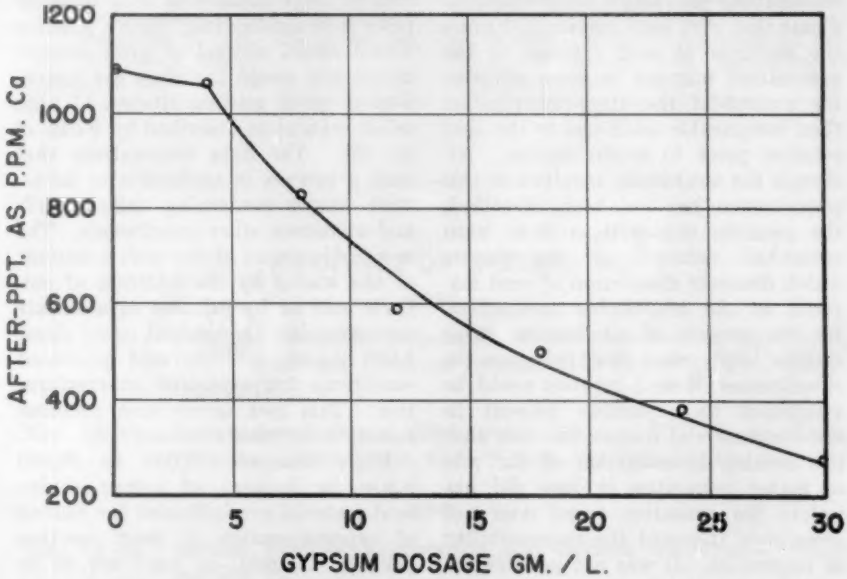

FIGURE 1.—Effect of gypsum addition on after-precipitation from high-calcium hydrated lime overneutralization of 5,000 p.p.m. sulfuric acid solution to pH 10.8. Acid temperature, 22.5° C.

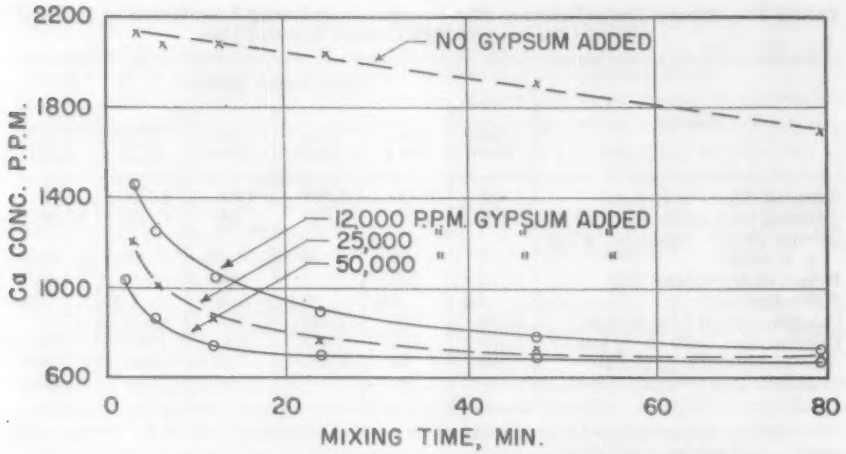

FIGURE 2.—Effect of gypsum dosage on rate of stabilization of calcium sulfate concentration following high-calcium lime overneutralization of 5,000 p.p.m. sulfuric acid solution to pH 10.2. Acid temperature, 24.0° C.

decrease in calcium concentration or calcium sulfate supersaturation.

Discussion

The results of these experiments substantiate previous studies which indicate that with some commercial limes the addition of seed crystals to the neutralized mixture is more effective for control of the after-precipitation than comparable additions to the acid solution prior to neutralization. Although the mechanism involved in this phenomenon has not been identified, the possible explanations have been somewhat reduced by experiments which discount dissolution of seed material as the responsible mechanism. By the process of elimination, these results imply that the reduction in effectiveness of seed crystals could be attributed to impurities present in some commercial limes. The fact that the ensuing investigation of the role of major impurities in lime did not isolate the causative agent does not completely discount the responsibility of impurities. It was not possible experimentally to duplicate impurities present in commercial lime from natural sources.

Of principal significance to practical application are the results which show that the control of calcium sulfate supersaturation during lime neutralization can be realized through the addition of large dosages of seed material prior to neutralization. Such a practice would afford control of after-precipitation and would facilitate the formation of quick settling sludges of high solids content as described by Faust *et al.* (3). The data demonstrate that such a process is applicable to industrial wastes containing mixed acids and numerous other constituents. The mere adjustment of the sulfate content of the wastes by the addition of sulfuric acid or by dilution to a sulfate concentration equivalent to about 6,000 p.p.m. sulfuric acid produced conditions for extensive supersaturation. This fact agrees with previous results with pure solutions (2).

High dosages (30,000 to 60,000 p.p.m. or higher) of return sludge seed material are indicated for control of supersaturation if short reaction periods (20 min. or less) are to be employed. These results are in good agreement with those of Scholander (5) which show that a dosage of 50,000

p.p.m. gypsum effectively desupersaturates calcium sulfate solutions in 20 min. These results are presumably at room temperature; therefore, lower dosages are indicated for higher temperatures. Sludge blanket type reactors incorporating vigorous agitation seem ideally suited for neutralization in the presence of high-return sludge solids.

Summary

An investigation of factors affecting control of calcium sulfate supersaturation by the addition of seed crystals before or after lime neutralization of sulfuric acid solutions has been made. With commercial lime neutralization, the addition of seed material following neutralization appeared more effective than comparable additions prior to neutralization. However, the difference in effectiveness could be compensated for by increased dosage. The mechanism responsible for the observed phenomenon was not found.

The data obtained for seed-crystal dosage and time of contact indicate that high dosages (30,000 to 60,000 p.p.m. or higher) are required to effect rapid stabilization of calcium sulfate concentration. A process in which neutralization is effected in the presence of a high concentration of return sludge solids is indicated for simultaneous control of supersaturation and production of rapid settling sludges.

Acknowledgment

This investigation was sponsored by the National Lime Association, Washington, D. C.

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MEETINGS OF INTEREST

1956

Nov. 27–30 **National Chemical Exposition,** Public Auditorium, Cleveland, Ohio. American Chemical Society, 1155 16th St., N.W., Washington, D. C.

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1957

Mar. 11–14 **Second Nuclear Engineering and Science Conference,** Philadelphia, Pa.

BLAST FURNACE FLUE DUST TREATMENT FACILITIES *

By William H. Weise

Works Metallurgist, American Steel and Wire Division, United States Steel Corporation, Cleveland, Ohio

Central Furnaces and Docks, a plant of the American Steel and Wire Division of the United States Steel Corp., is located on 40 acres of land adjacent to the Cuyahoga River in Cleveland's industrial valley. Employing 600 men, the plant produces more than 2,000 tons of various grades of merchant iron daily. Facilities include docks and ore storage, blast furnaces, sinter plant, and utilities.

Plant Facilities

Docks

Two docks, equipped with unloaders can handle ore boats of up to 10,000 gross tons capacity. During the shipping season last year, 170 cargoes of ore, totalling 1,350,000 tons, were unloaded. By the end of the shipping season, 650,000 tons of ore and 70,000 tons of limestone and other miscellaneous materials must be in storage to supply the furnaces during the winter months.

Furnaces

There are two blast furnaces; "A" and "D–6." Furnace "A" was placed in service in September 1954 and is the largest merchant iron furnace in the country. It is 228 ft. high over-all, with a 26-ft. hearth, and a rated production capacity of 1,250 tons per day. It incorporates modern gas cleaning and sludge recovery systems, modern stove construction, and many automatic control features. Furnace "D–6", built in 1911, has undergone many modifications with the latest rebuilding and modernization occurring in 1955. At this time new gas cleaning and sludge recovery systems were incorporated in the design along with modern stove construction. It has a 22.5-ft. hearth and a rated production capacity of 890 tons per day.

Utilities

The utilities to serve these two furnaces and the rest of the plant consists of a boiler house, generating station, pumphouse, and turbo blowers. The boiler house is equipped with six 1,200 h.p. water-tube boilers fired with blast furnace gas. The generating station has a 10,000 k.w. generator which supplies power for the furnaces and coke works. The pump house delivers cooling and washing water to the furnaces and provides plant service water for other miscellaneous uses. To provide air for the blast furnaces, there are two 75,000 c.f.m. (standard conditions) turbo blowers and one 110,000 c.f.m. turbo blower, each equipped with its own condenser water pumps. The sinter plant, built in 1955, can agglomerate 1,200 tons of ore fines and flue dust per day into a suitable charge material for the furnaces.

Blast Furnace Operation

As a background for the discussion of the treatment of blast furnace wastes, the operation and function of the furnace itself should be considered briefly. The blast furnace is a brick-lined steel vessel in which chemical reactions are carried out to reduce

* Presented at the 1956 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cleveland, Ohio; June 13–15, 1956.

iron ore to iron. Ore, coke, and limestone are continuously introduced into the top of the furnace. The ore, a mixture of iron oxide and impurities, is subjected to the reducing action of carbon monoxide, which is produced by the reaction of the coke with pre-heated blast air introduced near the bottom of the furnace. The limestone is added to flux the impurities and the coke ash. The combustion of the coke also provides the necessary heat to promote the reactions and to melt the products, iron and slag, which trickle down to the bottom of the furnace. The molten slag and iron are tapped off at intervals through openings in the hearth.

The scope of the blast furnace can be appreciated more readily in terms of materials used and products recovered. On furnace "A" a typical day's operation uses 2,500 tons of ore, 1,100 tons of coke, 400 tons of limestone and 4,000 tons of air to produce 1,250 tons of iron and 500 tons of slag. In addition, the blast furnace produces 6,000 tons of gas per day and about 180 tons of flue dust and sludge per day which represent the main items of waste treatment.

Gas Cleaning System

Initial Handling

The pre-heated air which is introduced in the lower part of the blast furnace forms carbon monoxide through reaction with the incandescent coke and passes up through the charge materials, reducing the iron oxide. The resulting gas, laden with entrained fines from the charged materials, is conducted off the top of the furnace through a cleaning system to condition it for use in the boiler house and in the stoves which pre-heat the blast. This gas leaves the furnace top at the rate of 100,000 c.f.m., with a heat value of 90 B.t.u. per cubic foot. At a temperature of 350° F. and containing 20 grains of dust per cubic foot, the gas travels down the downcomer, through the flared inlet into the dustcatcher. Then, reversing direction, it flows upward to the outlet. Much of the dust is dropped out by its own momentum. This dust (140 tons per day) is removed from the conical bottom of the dustcatcher through a pug mill where it is mixed with water before being discharged into a railroad car. The dustcatcher itself is a brick-lined steel cylinder 35 ft. in diameter and roughly 70 ft. in height.

Gas Washer Operation

The exit gas from the dustcatcher, still containing 3 grains of dust per cubic foot, travels into the bottom of the gas washer. It then flows upward through four banks of tile, countercurrently to the flow of washing water which enters the washer at two spray headers. The upper spray delivers 1,200 g.p.m. of water and the lower 1,500 g.p.m. The combined flow of water, with an average solids content of 123 grains per gallon, leaves the washer through a seal and enters a thickener. The washer itself is a steel cylinder 21 ft. in diameter by 80 ft. high.

Electrostatic Precipitator Treatment

The gas leaving the top of the gas washer has an average dust content of .15 grains per cubic foot. It passes through three electrostatic precipitators, arranged in parallel. The gas enters at the top, is split into two streams, and flows downward over baffles which distribute the gas over the entire cross section of the precipitator. It then passes up through 8-in. tubes, 300 in each precipitator. Here the dust is ionized and attracted to the tube walls over which a continuous film of water flows to carry the dust to the bottom of the precipitator. This dust-laden water, totalling 1,000 g.p.m. and containing 18 grains per gallon, flows through a seal into a thickener. The entire process is diagrammed in Figure 1.

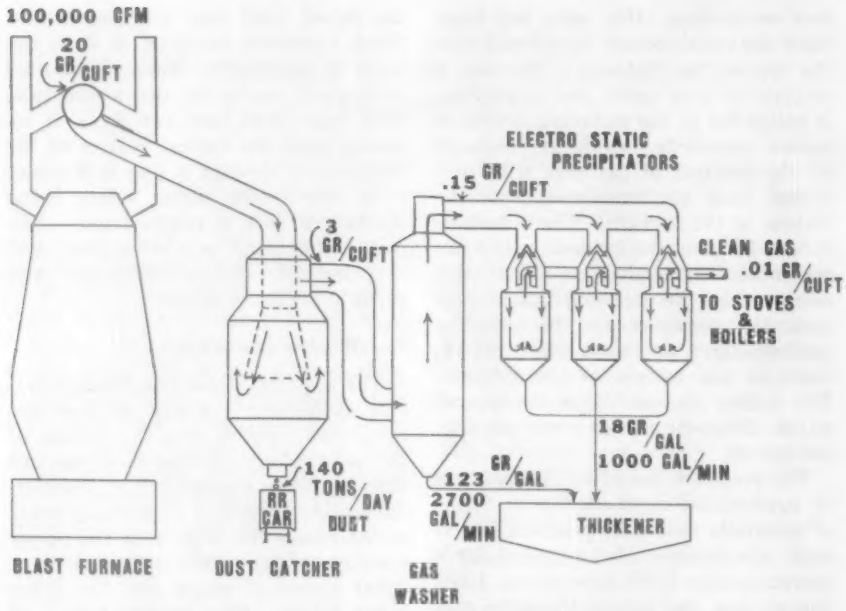

FIGURE 1.—Schematic drawing of blast furnace gas-cleaning system.

Resultant Gas

As a result of the processes described, the cleaned gas has a dust content of less than .01 grains per cubic foot. Gas this clean permits the use of smaller checkerbrick in the stoves which provides greater heating surface area per stove and makes possible the use of higher blast temperatures with a consequent improvement in furnace efficiency.

Water Requirements

The water requirements of a blast furnace are considerable. At Central Furnaces, 52,000 g.p.m. of service water are taken directly from the Cuyahoga River. The quality of this water is poor, but because of the great quantities used, a minimum of effort is made to condition it. On the suction side of the pumps, there is a ½-in. travelling screen to remove the larger pieces of debris. A typical analysis of intake water shows 5 grains per gallon of suspended solids. Figure 2 shows the river water distribution at the plant.

Sludge Recovery System

The sludge recovery system consists of conventional modern clarifying and filtering equipment. It does, however, have some unique layout features, influenced by the lack of space and the materials-handling problems inherent in the operation of this plant. Figure 3 shows the system and typical flow rates and solids contents of various influents and effluents.

Effluents from "A" Furnace

As previously indicated in Figure 2, the effluents from "A" gas washer (2,700 g.p.m. at 123 grains per gallon) and "A" precipitators (1,000 g.p.m. at 18 grains per gallon) flow into the furnace "A" thickener. This thickener is 60 ft. in diameter and 18 ft. deep at the center, with a holding capacity of 330,000 gal. Specification limits were set at 10 grains per gallon maximum and 7 grains per gallon av-

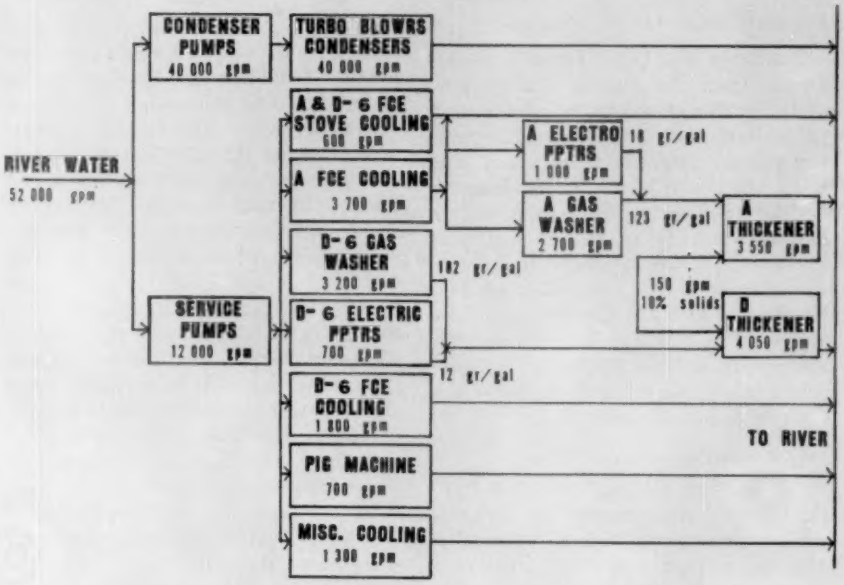

FIGURE 2.—Schematic drawing of water distribution.

erage for solids content in the effluent and were approved for installation by the state of Ohio. At the average rate of flow into the thickener, the detention time is 90 min. The effluent from the thickener to the sewer contains substantially less than 7 grains of solids per gallon.

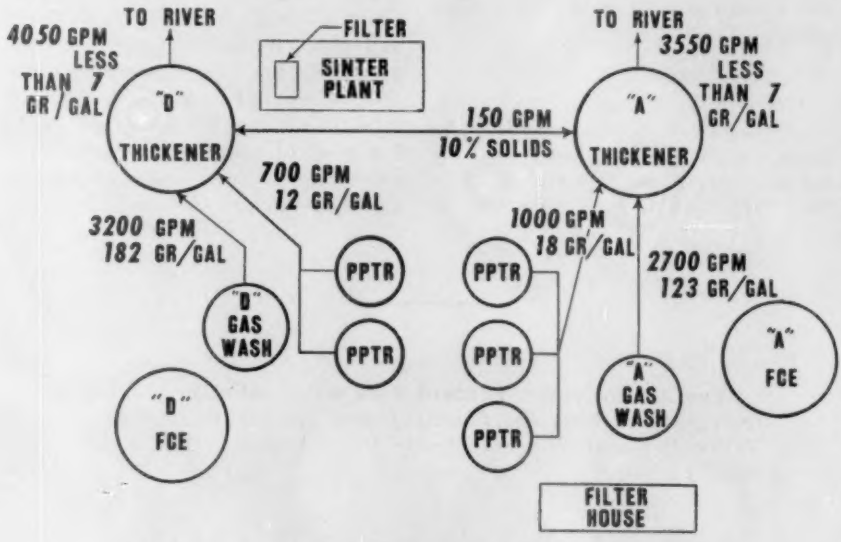

FIGURE 3.—Schematic drawing of sludge recovery system.

Effluents from "D–6" Furnace

Similarly at "D–6" furnace the effluents from the washer (3,200 g.p.m. at 182 grains of solids per gallon) and precipitators (700 g.p.m. at 12 grains per gallon) flow into a thickener. The "D" thickener is 50 ft. in diameter and 20 ft. deep at the center, with a holding capacity of 250,000 gal. At the average rate of flow, the detention time is 75 min. Specification limits similar to "A" furnace were also approved by the state of Ohio and the effluent from this thickener contains substantially less than 7 grains of solids per gallon of waste.

Interconnecting Line

A 4-in. line, linking "A" and "D" thickeners, interconnects the separate sludge recovery systems. Normally, diaphragm pumps at "A" thickener pump a constant 20 per cent solids underflow into a surge tank where it is automatically diluted with water and pumped to the "D" thickener feed well by a centrifugal pump. The diluted slurry is maintained at 10 per cent solids by adjusting the flow from the surge tank with a valve located on the discharge side of the centrifugal pump.

Filtering Process

When the underflow at "D" thickener reaches 60 per cent solids, the filter is started and operated until the underflow drops to 20 per cent solids. The filter, an 8.5-ft. diameter, 7-disc continuous vacuum type unit, is located on the second level of the sinter plant. The filter cake, a clayey mass of fine flue dust containing 27 per cent water, drops through a chute directly onto the final transfer belt running to the primary pug mill at the sinter plant. In this manner, the troublesome sludge is incorporated into the sinter mix with a minimum of difficulty.

When the sinter plant is shut down, the slurry is filtered on a spare 8.5-ft. diameter, 5-disc continuous vacuum type filter located in a filter house elevated over railroad tracks near "A" furnace. In this case the normal pumping procedure is reversed; the slurry is pumped from "D" to "A" thickener and the combined slurries are filtered over the spare filter for disposal at the dump.

Conclusions

In summary, the modernization of Central Furnaces and Docks has included these substantial improvements in blast furnace flue dust treatment facilities. The plant operates voluntarily under the permit system of the Ohio Water Pollution Control Board and plans for the facilities were approved by the Board before construction. With these facilities, the management of Central Furnaces and Docks has made a contribution toward improvement of water quality of the Cuyahoga River.

You are no further removed from water pollution problems than you are from the faucet in your kitchen sink.—Central Valley Regional Water Pollution Control Board, Sacramento, Calif. (1955).

Stream Pollution

AVOIDANCE REACTIONS OF SALMONID FISHES TO PULP MILL EFFLUENTS *

By Benjamin F. Jones,† Charles E. Warren, Carl E. Bond, and Peter Doudoroff

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Certain avoidance reactions of chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), coho salmon, *Oncorhynchus kisutch* (Walbaum), and steelhead trout, *Salmo gairdneri* (Richardson), to various dilutions of sulfate and sulfite pulp mill wastes under laboratory conditions are considered in this paper. The avoidance of fatal concentrations of toxic substances can favor survival of fish which might otherwise enter polluted waters such as those near industrial waste outfalls. On the other hand, avoidance of harmless substances or concentrations may render uninhabitable an otherwise suitable environment. Reliable observations on the reactions of fishes to pollution in natural environments are difficult to obtain. While laboratory studies are instructive they do not necessarily depict correctly the reactions of fish in actual environmental situations. Great caution must be exercised, therefore, in the interpretation and practical application of such data.

The reactions of fishes to differences in water quality have received considerable study, most of which has been in the laboratory. Shelford and Allee (1) and others have used gradient tanks with water having different characteristics introduced at opposite ends and draining at the middle. Jones (2) has used a horizontal cylindrical tube in like manner, and has been able to maintain a rather sharp boundary between altered and unaltered waters introduced at the two ends of the tube. Doudoroff (3) devised a compartmented gradient tank with numerous inlets and outlets for studying reactions to temperature. Chidester (4) had waters of different quality flowing down two troughs into a third one, from which fish could move up into one or the other of the confluent streams. Natural conditions probably have been approximated most nearly by Collins (5), who constructed a divided trough in a stream to study factors influencing the migration of anadromous fishes.

Apparatus similar to that of Collins was used by Smith and Saalfeld (6) in studying the avoidance of pulp mill wastes by Columbia River smelt, *Thaleichthys pacificus*. The work on the Columbia River smelt demonstrated that these fish will avoid a channel containing some concentra-

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tions of sulfate and mixed sulfate and sulfite process paper mill wastes, selecting instead a channel containing unaltered river water. Brett and MacKinnon (7) did not find the rate of movement of adult Pacific salmon over a fish ladder to be altered by the addition to the water of pulp mill wastes at concentrations far in excess of the concentrations of other substances which did cause a change of the rate of movement.

Methods and Materials

Two different types of apparatus were used in studying the reactions of some salmonid fishes to pulp mill wastes. The first of these was a modified gradient tank with transverse baffles. The second apparatus was a tank partitioned at one end into four parallel open channels, each equipped with an independent water supply and drain. In the first apparatus, the fish could select their preferred position in a gradient of stepwise increasing concentration of the substance examined. In the second apparatus, the fish in unaltered water were confronted with an abrupt change of water quality at the openings of two of the four channels, and they could choose between the altered water and unaltered water in the parallel channels.

The modified gradient tank was 10 in. high, 10 in. wide, and 115 in. long (inside measurements). Two compartments 20 in. long, one at each end of the tank, were formed by glass baffles which extended across the tank but which were raised 1 in. above the tank bottom. The remainder of the tank was divided into seven shorter compartments by means of transverse baffles placed alternately on opposite sides of the tank and extending 7 in. from the walls. The fish moved freely from one compartment to another. Water was introduced at the ends of the tank and overflowed through a standpipe in the middle compartment. Pulp mill waste was mixed with water entering at one end of the tank so as to create the desired gradient. The waste was introduced by means of a low-capacity chemical pump (8) at opposite ends of the tank in succeeding experiments. About 20 juvenile fish were used in an experiment, and each experiment lasted approximately 24 hr. The number of fish in each compartment was recorded at intervals. The per cent concentration of sulfate pulp mill waste in each compartment was determined by the Pearl-Benson nitrosolignin colorimetric test (9) with the aid of a photoelectric colorimeter.

The second apparatus used in these avoidance studies (Figure 1) consisted of a tank 12 in. high, 24 in. wide, and 112 in. long (inside measurements). This tank was enclosed in a separate compartment of the laboratory room to decrease disturbance of the fish. A two-tube, 96-in. fluorescent light fixture, when suspended from the ceiling of the white-walled compartment, provided quite uniform light throughout the tank. Four channels of equal width and 36 in. long, formed by plate glass partitions, were located at one end of the tank. Each channel had an independent adjustable water input at the closed end, and an independent adjustable drain at the open end. Each drain, the details of which are shown in Figure 1, was slotted to drain across nearly the entire width of a channel at a level 3 in. above the tank bottom. An oblique baffle prevented water from passing beneath the drains, and the water level was adjusted so that the tops of the drains were 2.5 in. beneath the water surface. When the outflow from a channel was adjusted to equal the inflow to the channel, experiments with dye added to the inflowing water showed that almost none of the water moving down the channel passed beyond the drain. A fairly sharp boundary between the water flowing through the channel and

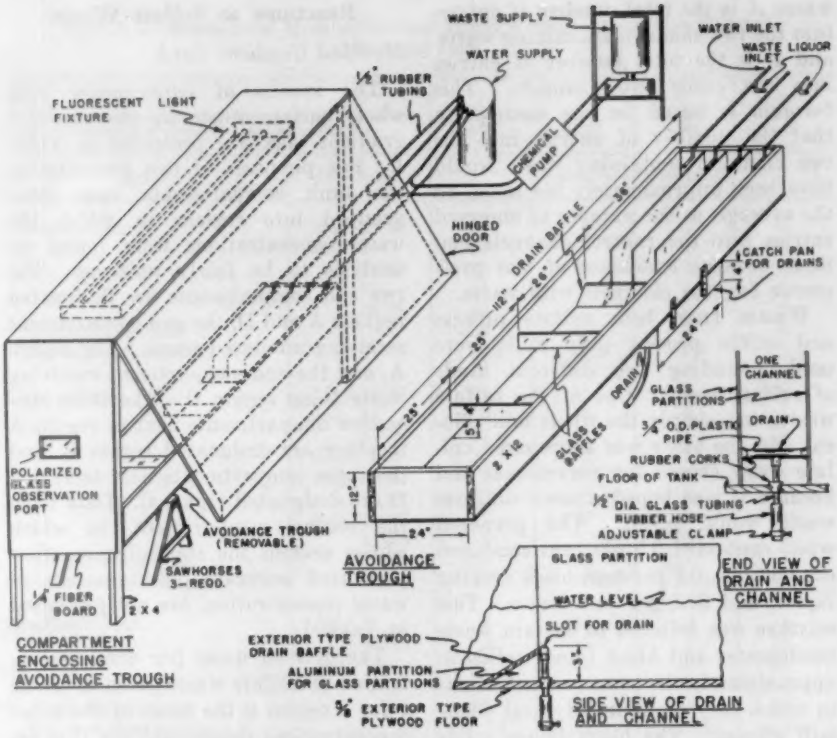

FIGURE 1.—Diagram of channeled avoidance trough used in avoidance reaction studies of salmonid fishes.

the water standing in the tank beyond the end of the channel thus was maintained. The wastes being studied were introduced into two of the four channels by means of a low-capacity chemical pump (8), so that alternate channels contained water with waste and water without waste.

Fish left undisturbed in the tank for a short time tended to swim about in an exploratory manner, entering and leaving the channels rather freely. Observations were usually made before waste was introduced, and the fish then exhibited no marked or consistent preference for either pair of alternate channels. In the course of the 42 control tests, 7,902 entries into one pair of channels and 7,683 entries into the other pair were recorded. An observation period of 1 hr. or less was usually sufficient for recording several hundred entries, but the number of entries recorded varied considerably between experiments. Once a fish had passed completely over a drain, a single entry was recorded and the fish was considered as having failed to avoid the channel entered, even if the fish then turned and left the channel. A larger measure of avoidance apparently would have been obtained if the criterion chosen had been (a) the relative frequency of passage across a line farther inside the channel, or (b) the total time spent by the fish in the different channels. The "per cent avoidance" as used in this study was computed by the formula:

$$\text{Per cent avoidance} = 100\ (E\text{-}A)/E$$

where A is the total number of entries into the two channels containing waste, and E is the total number of entries into the other two channels. This formula is based on the assumption that the number of entries into the two channels containing waste would have been approximately the same, on the average, as the number of observed entries into the control channels had there been no avoidance of, nor preference for, the channels with waste.

Wastes from both sulfate process and sulfite process pulp mills were used, including two different kinds of sulfate waste. One of the sulfate wastes was simply the whole mill effluent and the other was a prepared sulfate waste chosen for convenience and because it was hoped a more uniform waste would result. The prepared waste contained 9.0 per cent combined condensates, 0.2 per cent black cooking liquor, and 90.8 per cent water. This mixture was believed to contain waste condensates and black liquor solids in approximately the same concentrations in which they occur in a typical whole mill effluent. The black liquor solids in the mill effluent are contributed by waters which have been used for washing pulp. The sulfite waste used in the experiments was calcium-base spent sulfite liquor of digester strength and of known total solids content. The concentrations of waste in the dilutions are expressed as parts per million of a sulfite waste liquor having 10 per cent total solids.

The steelhead trout, coho salmon, and chinook salmon used in these studies usually were obtained by seining in nearby rivers and were held in tanks for variable periods of time before being used. They were fed on alternate days. Hatchery-reared chinook salmon were used during the fall when wild fish were not available. All fish used were vigorous and apparently healthy. The fish ranged in total length from about 50 to 160 mm.

Reactions to Sulfate Waste

Modified Gradient Tank

The results of experiments with whole sulfate waste in the modified gradient tank are presented in Table I. For purposes of this presentation the tank compartments have been grouped into regions in which the waste concentrations were found by analysis to be fairly uniform. The two end compartments are designated regions A and D, the end compartment receiving unaltered water being region A, and the end compartment receiving waste being region D. The three successive compartments next to region A together are designated region B, and the three compartments next to region D are designated region C. Data from the central compartment, in which eddies around the standpipe overflow prevented accurate determination of waste concentration, are not presented in Table I.

The over-all mean per cent concentration of sulfate waste given in Table I for a region is the mean of the mean concentrations determined for that region in all experiments. The standard deviation of mean concentrations obtained in individual experiments from the over-all mean concentration for each compartment is given. Table I also shows the number of fish observed in each region in every experiment, the total number of fish observed in each region in all experiments, and the percentage of all the observations that this total represents.

Chinook salmon exhibited the greatest avoidance of regions containing waste, coho salmon exhibited considerably less, and steelhead trout showed no marked reactions.

In each of five experiments with chinook salmon, the greatest number of fish was observed in region A, and only 3.2 per cent of all the observations were recorded for regions C and D combined, the regions with the high-

TABLE I.—Reactions of Juvenile Salmonid Fishes to Sulfate Waste in a Modified Gradient Tank

Region Over-all mean concentration of waste as per cent by volume Standard deviation of mean per cent concentrations		A 0.0 0.00	B 1.5 0.20	C 4.3 0.84	D 4.8 0.80
Species	Date (1953)	Number of Fish Observed			
Chinook salmon	May 28–29	36	7	0	0
	Jun. 4	23	19	1	5
	11–12	93	16	0	0
	13	32	2	1	1
	18–19	46	3	1	0
Total observations		230	47	3	6
Per cent observations		80.4	16.4	1.1	2.1
Coho salmon	May 26–27	21	15	8	8
	Jun. 19	0	38	3	5
	29–30	27	11	1	13
	Jul. 1–2	27	12	7	13
	Aug. 5–6	72	61	3	11
	8–9	28	40	8	14
	Sep. 11–12	11	49	81	3
	14–15	6	27	20	4
Total observations		192	253	131	71
Per cent observations		29.7	39.1	20.2	11.0
Steelhead trout	Jul. 21	3	14	3	4
	23–24	4	3	4	15
	Sep. 3–4	17	46	49	15
	16–17	3	42	103	9
Total observations		27	105	159	43
Per cent observations		8.1	31.4	47.6	12.9

est waste concentrations. The greatest number of coho salmon occurred in either region A or region B in seven of eight experiments, but 31.2 per cent of all observations were made in regions C and D combined, where the over-all mean waste concentrations were 4.3 and 4.8 per cent. The steelhead trout tended to avoid the two end compartments regardless of the presence or absence of waste. The percentage of fish occurring in the two compartments having the higher waste concentrations actually was greater than the percentage of fish occurring in the other two compartments. This difference probably was not statistically significant, only four experiments having been conducted with the steelhead trout, and the results of these experiments having been rather variable.

Channeled Avoidance Tank

The channeled avoidance tank (Figure 1) was used to study the reactions of chinook and coho salmon to both whole sulfate pulp mill waste and to prepared sulfate waste containing combined condensates and black liquor in fixed proportion. The results of these experiments with sulfate wastes are presented in Tables II and III. As in the modified gradient tank, chinook salmon in the channeled tank generally exhibited greater avoidance than did coho salmon. Greater avoidance was shown of the waste prepared from combined condensates and black liquor than of the whole sulfate mill waste.

Table II presents data on the avoidance by both juvenile chinook and coho salmon of different concentrations of sulfate waste prepared with combined

condensates and black liquor. For each experiment, the numbers of entries into the experimental and control channels, as well as the computed per cent avoidance, are given. The estimated means for the per cent avoidance at the various concentrations are arithmetic. The 95 per cent confidence limits for the means are also given in Table II (see footnote under "Reactions to Sulfite Waste").

Chinook salmon consistently exhibited marked avoidance of 10 per cent and 5 per cent dilutions of the prepared sulfate waste. With one notable exception, some avoidance of 2.5 per cent waste was shown in each test. In the three tests with 1.25 per cent waste dilutions, however, the fish seemed to show a consistent though not very pronounced preference for water containing the waste. Although this is not by any means conclusive evidence that low concentrations of the waste are attractive, it is conceivable that the waste in question has attractive as well as repellent properties.

Whether the fish are repelled or attracted by any given concentration may depend on the dominance of the repellent or the attractive stimulus. For example, reduced light intensity due to the dark color of the waste may possibly be an attractive visual stimulus, resulting in at least momentary preference for channels containing waste in concentration not great enough to be promptly and strongly repellent chemically. This can serve as a tentative explanation of the observation that chinook salmon seemed to be attracted by waste tested in December at a concentration of 2.5 per cent, which concentration was evidently repellent in tests performed in August and September. It will be

TABLE II.—Avoidance by Juvenile Salmon in the Channeled Avoidance Tank of Sulfate Waste Prepared with Combined Condensates and Black Liquor

Species	Waste Conc. (per cent by volume)	Date	Number of Entries				Per Cent Avoidance	Estimated Mean Per Cent Avoidance	95 Per Cent Conf. Limits of Mean Per Cent Avoidance
			Waste	Control	Waste	Control			
		(1954)							
Chinook	10	Aug. 17	9	197	16	196	93.7		
		Sep. 31	2	47	5	43	92.2		
		7	1	16	3	17	87.9		
		Nov. 19	122	471	46	344	79.4		
		26	43	377	89	292	80.3	86.7	78.5; 94.9
Chinook	5	Aug. 16	48	128	53	156	64.4		
		30	6	31	4	26	82.4		
		Sep. 8	31	89	35	102	65.4		
		Nov. 30	45	111	48	83	52.1	66.1	45.5; 86.7
Chinook	2.5	Aug. 10	145	262	81	352	63.2		
		12	42	80	30	60	48.6		
		25	52	89	81	65	13.6		
		Sep. 9	23	28	31	37	16.9		
		Dec. 3	109	77	136	90	−46.7	19.1	−33.4; 71.6
Chinook	1.25	Aug. 18	35	34	79	60	−21.3		
		24	26	19	21	27	− 2.2		
		Dec. 11	152	66	74	115	−24.9	−16.1	−46.4; 14.2
Coho	10	Dec. 29	157	207	187	181	11.3		
		(1955)							
	5	Jan. 8	326	277	339	337	− 8.3	—	—

TABLE III.—Avoidance by Juvenile Salmon of Whole Sulfate Waste in the Channeled Avoidance Tank

Species	Waste Conc. (per cent by volume)	Date	Number of Entries				Per Cent Avoidance	Estimated Mean Per Cent Avoidance	95 Per Cent Conf. Limits of Mean Per Cent Avoidance
			Waste	Control	Waste	Control			
		(1954)							
Chinook	10	Jul. 19	84	163	123	168	37.4		
		20	157	305	197	302	41.7		
		21	92	113	88	242	49.3		
		Dec. 22	197	289	237	269	22.2	37.7	19.5; 55.8
Chinook	5	Jul. 28	76	162	90	148	46.4		
		Aug. 5	90	179	99	229	53.5		
		(1955)							
		Jan. 15	178	168	174	169	− 4.5	31.8	−31.8; 95.4
		(1954)							
Chinook	2.5	Jul. 23	26	25	34	48	17.8		
		26	50	37	47	61	1.0		
		28	77	111	90	106	19.3		
		Aug. 6	53	60	72	84	13.2	12.8	0.4; 26.0
		(1955)							
Coho	10	Jan. 22	142	116	113	99	−18.6	—	—

noted that the percentage of avoidance of each test concentration was lower in late November or early December than in August and September, suggesting a decrease of the repellent potency of the waste.

Although the waste samples were obtained from a single pulp mill, differences between the samples taken at different times, due to variations of mill operation and other factors, probably account for much of the wide variability of the experimental results. Changes of the physiological state of the fish, decreasing temperatures, and other factors also may have had an effect. Most of the variability of recorded percentages of avoidance of a single concentration of waste may be referable to chance differences (which often were quite large) between the numbers of entries into the two pairs of channels under comparison during individual control periods when no waste was introduced. Nevertheless, in view of the preceding considerations, the significance of the reported mean percentages of avoidance, based on data obtained at different times and with different waste samples, is admittedly questionable.

Coho salmon showed no very marked avoidance of the sulfate waste prepared with condensates and black liquor in concentrations which were always definitely avoided by chinook salmon. They even seemed to be slightly attracted by a 5 per cent waste dilution. Only two experiments were performed with coho salmon. The fact that the experiments with the chinook salmon were performed earlier may possibly account for some of the difference between the results obtained with the two species.

Table III presents data on the avoidance by juvenile chinook and coho salmon of different dilutions of whole sulfate waste. Some avoidance by chinook salmon of this whole waste in concentrations as low as 2.5 per cent is indicated, but again tests performed in December showed but little or no avoidance of higher concentrations (10 per cent and 5 per cent). Earlier, the avoidance of the higher concentra-

tions was more pronounced, though not as marked as the avoidance of corresponding concentrations of prepared waste. Coho salmon, in a single experiment with this species performed in January, showed no avoidance of a 10 per cent dilution of the whole waste, but instead seemed to show some preference for channels containing waste.

Amberg (10) has shown the toxicity to coho salmon of sulfate wastes to be highly variable. These wastes were from the pulp mill which provided the similar wastes used in the avoidance studies. The fish were held in bottles through which mixtures of water and waste flowed continuously. A prepared waste containing 16.7 per cent combined condensates and 0.2 per cent black liquor proved somewhat toxic at a concentration of 6.0 per cent. This concentration was tolerated by 8 of 10 fish for 45 and 120 hr., but killed one-half of the fish in 200 hr. An 8.0 per cent dilution killed 4 of 10 fish in 45 hr. and all of the fish within 100 hr., whereas 4.0 per cent waste and lower concentrations killed no fish in 120 hr. Some of the condensate samples used by Amberg proved more toxic and some proved less toxic than the one used in preparing this waste. The prepared wastes used in the avoidance studies contained 9.0 per cent combined condensates, rather than 16.7 per cent, and thus probably were not usually as toxic as the waste used in this toxicity test. It appears that the 10 per cent dilutions of prepared waste used in the avoidance studies would usually have proved somewhat toxic to salmon.

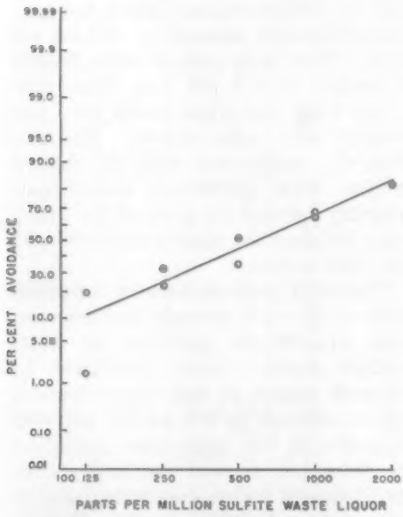

FIGURE 2.—Avoidance reaction of chinook salmon to sulfite waste liquor.

During the course of these avoidance studies, juvenile chinook salmon exhibiting symptoms of intoxication with sulfate waste have been observed in a stream situation where avoidance of the polluted area should have been possible. Since avoidance even of 10 per cent waste dilutions in the laboratory was not total, such an observation is not surprising. Furthermore, conditions in the field and in the laboratory differ in many respects.

Reactions to Sulfite Waste

The avoidance reactions of juvenile chinook and coho salmon to various concentrations of a single sample of sulfite waste liquor in the channeled avoidance tank are presented in Figure 2 and Table IV. The chinook salmon exhibited considerably more avoidance of the sulfite waste liquor than did the coho salmon.

Figure 2 illustrates that, for the concentrations examined, a straight-line relationship exists between the per cent avoidance by chinook salmon and the concentration of sulfite waste liquor when the avoidance is plotted on a probit scale and the concentration on a logarithmic scale. The straight regression line shown was selected by the method of least squares.

Table IV includes the per cent avoidance of different concentrations of sulfite waste exhibited by chinook and coho salmon in each of 12 experiments. The estimated mean percentages of avoidance given at each concentration for the chinook salmon are taken from the regression line shown in Figure 2. The 95 per cent confi-

TABLE IV.—Avoidance by Juvenile Salmon of Sulfite Waste Liquor in the Channeled Avoidance Tank

Species	Waste Conc. (p.p.m.)*	Date	Number of Entries				Per Cent Avoidance	Estimated Mean Per Cent Avoidance	95 Per Cent Conf. Limits of Mean Per Cent Avoidance
			Waste	Control	Waste	Control			
		(1954)							
Chinook	2,000	Sep. 23	27	175	70	346	81.4	82.4	57.2; 95.4
Chinook	1,000	Oct. 16	102	345	169	427	65.2		
		Nov. 6	40	217	108	229	66.8	65.4	35.7; 87.7
Chinook	500	Oct. 23	131	250	175	392	52.3		
		Nov. 9	74	156	82	83	34.8	44.5	20.5; 70.9
Chinook	250	Oct. 23	226	285	207	278	23.1		
		Nov. 13	106	178	97	127	33.4	25.1	7.1; 55.0
Chinook	125	Oct. 23	189	219	211	281	20.0		
		Nov. 13	244	316	212	162	4.6	11.4	2.5; 32.3
Coho	2,000	Sep. 21	151	332	248	145	16.4		
		Sep. 22	320	280	224	336	11.7	14.0	—
Coho	1,000	Oct. 9	148	194	218	165	−1.9	—	—

* Sulfite waste liquor having 10 per cent solids.

dence limits for the mean at each concentration are based on the estimates given by the regression equation and the standard error of these estimates.*

* The general form of the regression equation on which these estimates and confidence limits are based was determined empirically and has no particular theoretical basis. It will be noted that these confidence limits are distributed asymmetrically about an estimated mean. This occurs because at high and low waste concentrations the distributions of per cent avoidance tend to be skewed, avoidance percentages higher than 100 per cent being impossible, and avoidance percentages much less than zero per cent being improbable, though theoretically not impossible. The confidence limits for the mean percentages of avoidance of sulfite waste would appear symmetrically distributed about the means when plotted on a probit scale. In computing the confidence limits for the mean percentages of avoidance of sulfate waste (Tables II and III) the distributions of these avoidance percentages were assumed to be normal, which assumption is not valid at high and low waste concentrations at which the mean avoidance percentages were either considerably above or below 50 per cent. Consequently, the confidence limits shown in Tables II and III are symmetrically arranged about the estimated means.

While chinook salmon exhibited considerable avoidance of sulfite waste liquor in concentrations of 2,000 and 1,000 p.p.m., coho salmon exhibited little avoidance at concentrations of 2,000 p.p.m. and no avoidance at a concentration of 1,000 p.p.m. (one test only). Chinook salmon exhibited a little avoidance of concentrations as low as 125 p.p.m.

Some work has been done in the state of Washington on the long-term toxicity of sulfite waste liquor to juvenile salmon (11). The toxicity of sulfite waste liquor to juvenile salmon in fresh water appeared in part to be dependent on the age or the size of the fish. In experiments lasting for 30 days, the "median lethal dosage" (lowest concentration expected to kill 50 per cent) for chinook salmon 305 days old was 805 p.p.m. sulfite waste liquor of 10 per cent solids content. The "threshold index," or the approximate concentration expected to kill 5 per cent of these fish, was 575

p.p.m. The "median lethal dosage" for coho salmon 351 days old was 1,700 p.p.m., and the "threshold index" was 1,225 p.p.m.

From the above toxicity data and from the avoidance studies reported herein, it would seem that juvenile chinook salmon exhibit considerable avoidance of toxic concentrations of sulfite wastes. Juvenile coho salmon apparently do not exhibit as sharp an avoidance of concentrations of comparable toxicity. Some avoidance of sulfite waste concentrations as low as 125 p.p.m. by chinook salmon is indicated (Table IV) and this concentration could not be expected to be fatal. Concentrations of approximately 125 p.p.m. of sulfite waste liquor are not unusual in certain receiving waters in the Pacific Northwest. Greater concentrations often may be expected to result in serious reduction of dissolved oxygen.

It is interesting to find that two such closely related species as chinook and coho salmon exhibit markedly different avoidance reactions under laboratory conditions to both sulfate and sulfite pulp mill wastes. The toxicity of sulfite waste apparently is somewhat greater to chinook salmon than to coho salmon. The difference of avoidance reactions may or may not have a direct relation to the difference of tolerance between the two species.

Summary and Conclusions

The avoidance reactions of juvenile chinook salmon and coho salmon to waste from sulfate and sulfite process pulp mills, and also the reactions of steelhead trout to sulfate waste, were investigated. Two types of apparatus were used for these studies. One was a modified gradient tank with baffles, the other was a tank partitioned into four parallel channels at one end. In the latter, two of the channels received water containing waste and two received unaltered water.

In the modified gradient tank, four regions had over-all mean concentrations of sulfate waste ranging from 0.0 to 4.8 per cent by volume. Chinook salmon showed marked avoidance of the regions containing sulfate waste, while coho salmon showed much less avoidance. No avoidance of the tested concentrations by steelhead trout was observed.

The reactions of juvenile chinook and coho salmon to various dilutions of whole sulfate waste and of a waste prepared with combined condensates and black liquor were studied in the channeled avoidance tank. Chinook salmon always tended to avoid both of these wastes at a concentration of 10 per cent by volume, the avoidance of the prepared waste being the more pronounced. Lower concentrations were not so consistently or as markedly repellent, and in some instances seemed to be somewhat attractive, but considerable avoidance of 5 per cent and 2.5 per cent waste dilutions was indicated by the results of most of the tests of these concentrations. Coho salmon showed little or no avoidance of 10 per cent and 5 per cent waste dilutions in the few tests performed with this species.

The reactions of juvenile chinook and coho salmon to sulfite waste liquor were studied in the channeled avoidance tank. Chinook salmon showed very marked avoidance of this waste when the concentration of the liquor (with 10 per cent solids content) was 2,000 p.p.m., and progressively decreasing avoidance of progressively lower concentrations. The tendency to avoid 125 p.p.m. of the liquor was only slight. Coho salmon showed little or no avoidance of 2,000 p.p.m. and 1,000 p.p.m. sulfite waste liquor dilutions in a few tests performed with this species.

The data obtained with the channeled avoidance tank indicate only the degree or frequency of instantaneous

avoidance exhibited at the entrances to the channels. Where little or no such immediate avoidance was recorded, it should not be assumed that delayed avoidance was not more pronounced than the immediate avoidance.

It is apparent that further experiments are needed for evaluating delayed as well as instantaneous avoidance of the various waste dilutions by different salmonids, in the channeled avoidance tank. The possibility that some low concentrations of waste may be attractive should be studied thoroughly and the degree of avoidance of waste dilutions should be related more accurately to their toxicity.

Acknowledgments

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CONFERENCE OF FEDERAL SANITARY ENGINEERS

Officers of the Conference of Federal Sanitary Engineers elected for the year beginning June 1, 1956 are Gordon McCallum (USPHS), President; Mark D. Hollis (USPHS), President-elect; and Alvin F. Meyer, Jr. (USAF), Secretary-Treasurer. In addition, a 9-member Board of Directors was elected representing the Army, Navy, Air Force, and Public Health Service.

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THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

OPEN-DIGESTER SCUM CONTROL

BY GEORGE T. LOHMEYER

Superintendent, Sewage Treatment Plant, University of Florida, Gainesville, Florida

A universal problem which must be met in the proper operation of digesters is the control of the masses of floating solids, usually high in volatile content, which form on the surface of the tank and are generally referred to as the scum blanket. Only in a grossly underloaded digester do these floating solids not create a difficult problem. Without scum control the effective capacity of a digester can be eventually reduced so that the digester is totally ineffective.

The following comments relate the experiences encountered in overcoming a serious scum problem with an open unheated digester.

Open unheated digesters are not uncommon where winter conditions are mild and full utilization of digester gas is not necessary. The digesters at the University of Florida sewage treatment plan consist of two 30-ft. diameter tanks, each with an effective depth of 20 ft. The total volume of both tanks provides 4.0 cu. ft. of volume per capita for a design contributory population of 7,000. Standard gas collection, heating, and operational equipment is provided for both digesters. The floating cover was intentionally omitted from one digester when the treatment plant was constructed so that a study could be made on the feasibility of operating an open unheated digester in Florida.

All sludge has been handled by the open unheated digester since the University sewage treatment plant was placed in operation in September 1947, except for a short period during the 1949–50 school year. The B.O.D. equivalent contributory population for the 1955–56 school year averaged 8,000, which amounted to a loading rate of 1.75 cu. ft. per capita. The secondary treatment units consist of a 112-ft. diameter standard-rate trickling filter and a 40-ft. diameter high-rate filter. Trickling filter humus is settled in secondary clarifiers, designed on a 2.5-hr. detention period before it is pumped to the primary clarifiers. In the absence of a sludge thickening tank, the open digester is loaded with sludge pumped directly from the primary clarifiers. The primary clarifiers were designed for a 2.0-hr. detention period.

From the start of the open-digester operation study the chief difficulty encountered was a heavy scum blanket which formed to a depth of 6 to 7 ft. With such a condition 30 per cent of the tank capacity was rendered ineffective, and was reflected by the high solids content of the supernatant. Furthermore, pockets of raw solids formed in the scum blanket directly over the raw sludge pipe inlet, creating an unsightly and fly-attractive nuisance. The feasibility of using open sludge digesters depended upon the elimination of this nuisance. Several

methods were tried to break up the scum in an economical manner.

Recirculation

An early attempt was made to disperse the scum formation by recirculating with the existing sludge recirculation pumps from the 6-ft. level to alternate vertical discharge points in the digester; one in the center above the scum level and two below the scum formation. Although small openings were formed in the scum blanket at the recirculation discharge points the scum layer itself remained solid.

Rodding

The use of long-handled plungers, even though crude and primitive, proved a fair means of controlling the scum blanket. However, the time required to accomplish a satisfactory job was excessive. Furthermore, there was the ever-present danger of an operator falling into the tank.

Physical Removal

A dragline equipped with a clamshell was used occasionally for physically removing the scum to dump trucks which hauled the solids to pits for disposal. This method was costly and unavoidably messy, and could be considered only as an emergency procedure.

Portable Pump Recirculation

A portable gasoline powered centrifugal pump, rated at 10,000 gal. per hour, was used next for the scum breaking operation. With a strainer attached, the pump intake was forced through the scum blanket into the supernatant zone. At weekly intervals liquid was pumped from this level and discharged over the scum blanket for periods varying from 6 to 8 hr. A fair degree of scum control was attained although the method was time consuming.

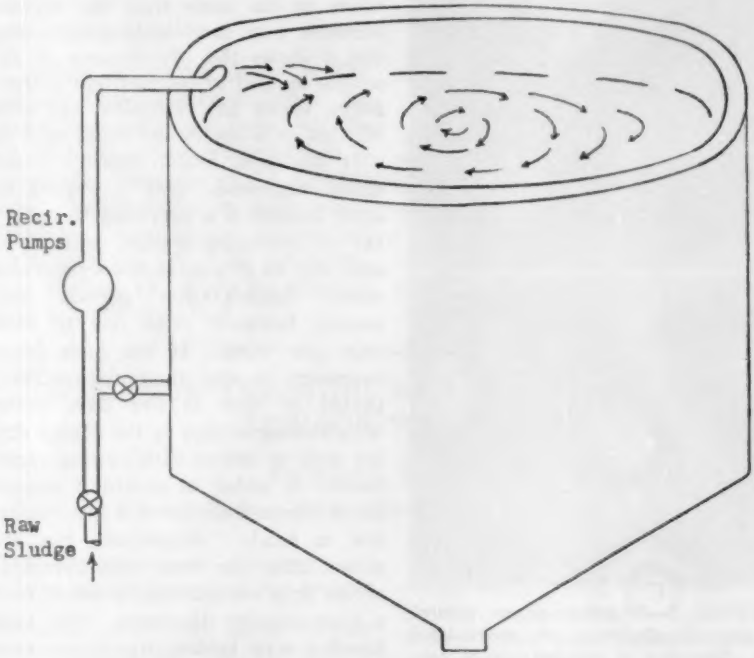

FIGURE 1.—Simple sludge recirculation system for open digesters.

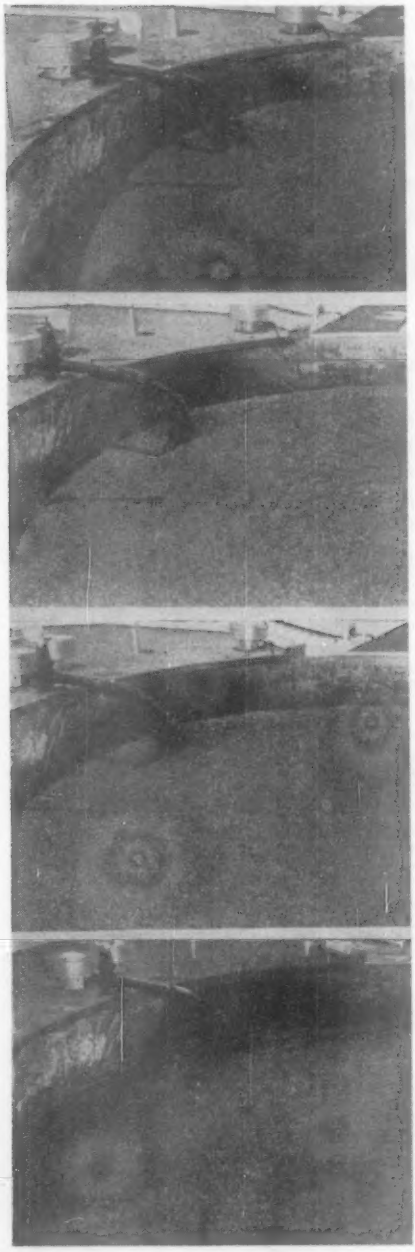

FIGURE 2.—Effective scum control with angular discharge of recirculated sludge. Sequence of pictures, top to bottom: 10 AM, 11 AM, 11:30 AM, and 1 PM.

Angular Discharge Recirculation

The next idea for controlling the scum blanket was first suggested by Mr. E. A. Cox, Consulting Engineer, Oak Ridge, Tenn., in November 1954. He suggested that the recirculated sludge be discharged above the scum blanket adjacent to the digester wall at an angle to the liquid level. The recirculation system is simple (Figure 1). Sludge is drawn from the 6-ft. level by two bladeless impeller centrifugal pumps, each rated at 75 g.p.m. and powered by ¾-h.p. motors.

Prior to using this method the scum layer measured more than 6 ft. in thickness. After a week of recirculation the scum was completely broken up. Floating solids followed a spiral path from the center of the digester surface to the digester wall where the floating scum particles were plunged beneath the liquid level by the discharging sludge. A complete dispersion of the scum blanket was achieved, while at the same time the digester contents were thoroughly mixed. Figure 2 shows the effectiveness of this simple method of intermittent recirculation which has controlled the scum blanket at a maximum depth of 6 in.

It has been found, through subsequent experience, that to control the scum blanket it is necessary to operate the recirculation pumps only 6 hr. each day on two consecutive days each week. Recirculation periods have varied, however, from one to three days per week. It has been found necessary to stop recirculation for a period of four to five days before withdrawing sludge to the sludge drying beds or before withdrawing supernatant in order to obtain a consolidated digested sludge or a supernatant low in solids. Experience has also shown that the best scum breaking action does not necessarily result from a high velocity discharge. The scum blanket was broken up much more rapidly by a lower velocity discharge

which splashed over a maximum surface area of the scum.

Advantages of Angular Discharge Recirculation

In addition to completely controlling the scum blanket, the described system of recirculation has been found to possess other inherent advantages as well.

Mixing

By achieving a circulatory motion the entire digester contents are completely mixed. Raw solids in the digester are seeded with active organisms and alkaline liquors, and the pocketing of these solids in the scum layer is eliminated. Furthermore, flies have not been observed around the digester since the start of the revised recirculation system and fly larvae have not been observed. Odors are not present, even in the immediate digester area.

Digester Sampling

A sample of sludge taken at the point of sludge discharge after the digester contents have been recirculated for a period of several hours is an excellent composite of the digester sludge. The increase in total solids within the digester is determined weekly until an optimum concentration is reached, at which time digested sludge is withdrawn.

Solar Heating

In an effort to conserve the digester heat which was inherent in the raw sludge entering the tank, the recirculation system was operated only during hours of direct sunlight or when the temperature of the air slightly exceeded that of the digester. As a result, a crude solar-heated digester was devised whereby the heat rays from the sun struck a thin layer of surface sludge which absorbed the heat. As the digesting solids were circulated, the digester was slightly warmed by this heated sludge as it mixed into the tank at the point of sludge discharge. During one 8-hr. period of recirculation during the summer a 0.7° F. rise in digester temperature was measured.

Although the solar heating was incidental to the chief objective of the recirculation system, it might indicate the need of directing research toward the possibility of heating digesters in semi-tropical climates by solar energy.

Conclusion

In reporting these experiences in controlling a digester scum blanket it is fully realized that no new principles, either in sludge recirculation or scum control, have been applied. The efficiency of controlling digester scum by using an angular discharge of recirculated sludge above the scum blanket is a simple system that does not need to be restricted to open digesters.

OPERATOR TRAINING PROGRAM FOR LARGE SEWAGE WORKS *

By Arthur D. Caster

Principal Engineer, Sewage Disposal Section, Cincinnati, Ohio

Training programs, whereby potentially capable personnel are trained in the skills necessary to become efficient, well-adjusted employees, have become a standard medium in industry. Such programs should not be overlooked by sewage and industrial waste treatment facilities, particularly

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in view of the rapid increase in treatment facilities and the shortage of trained personnel. Every sewage treatment works, large or small, has different features that must be explained to the operators (especially the new operators), whether they have seen sewage treatment works before or whether they are coming strictly as neophytes from agricultural areas or industry.

A training program was necessary at Cincinnati, Ohio, because a basic core of trained operators was not available to explain processes and procedures to the new operators. There are certain fundamental advantages to any sewage treatment works that can be incurred through a properly organized training program.

1. The operator can become more familiar with what he is doing, thereby relieving some of the load on the foreman.
2. The foreman will be more confident of the operator's work.
3. The chief operator and superintendent will be relieved of some of the routine duties necessary when the working staff is not properly trained, both from an operational and psychological safety standpoint.

A training program planned to instruct personnel with varied educational backgrounds and experience requires careful planning. At the Cincinnati sewage treatment works the education of the personnel ranged from the eighth grade to college.

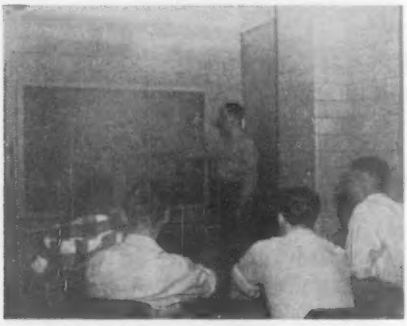


FIGURE 1.—Operator training featuring a "chalk talk."

To prepare an effective training program liberal use is made of visual and audio aids. Slides, motion pictures, "chalk talks" (Figure 1) and actual demonstrations are combined to present the background material necessary for an understanding of the treatment processes, and to instruct in specific duties. Written material is utilized for reference work and outside study. Periodic examinations served as guides to the instructional staff as to the effectiveness of the course and the sections in which the students are weak. The training program is patterned on the training courses established by the armed services for the instruction of recruits. The basis of the program is the generous use of pictures.

Equipment

The Cincinnati Sewage Disposal Section is fortunate to have the backing of administrative officials who favor adequate training aids. Four principal pieces of equipment are used:

1. A 16-mm. sound motion picture projector.
2. A 3-in. by 4-in. and a 2-in. by 2-in. slide projector.
3. A tape recorder.
4. A graphic viewer.

In addition, cut-away sections of particular pieces of equipment such as valves are used, and when possible equipment is brought into the lecture room.

Motion Picture Projector

The motion picture projector is used to show films prepared by various equipment manufacturers or public agencies. A movie was made during the construction of the various works for the Cincinnati sewerage program. This film takes the operator through the construction of a sewage treatment plant, showing the actual pouring of

concrete for the foundations and the laying of piping which was later covered. Films made during the erection of equipment such as digester floating covers or the installation of various units, such as sludge collectors or vacuum filters, are shown for the edification of the operator and maintenance man. These installation films are particularly valuable to the maintenance men who are then better able to visualize the function of the equipment and the location of vital sections should repairs be necessary.

The production of the "shorts" on the operation of various pieces of equipment and the construction films required considerable time and patience, both in the field and in the cutting room. Most of the filming was done by plant personnel and experience indicated that about 4 ft. of film had to be exposed for every foot of useable film.

Slide Projector

The slide projector is used to present slides showing cut-away sections of equipment, interesting units in the plant, graphs, chemical experiments and equations. In fact, slides are used wherever an explanation is necessary. Slides are used to illustrate the instructor's talks.

To facilitate lecturing, a fully automatic 2-in. by 2-in. 500-w. slide projector is used. This permits the instructor to stand facing the class and to point out pertinent features in the projected picture.

Tape Recorder

The tape recorder is used to prepare general or "stock" talks which can be used repeatedly to orient and instruct new personnel. Effective use is made of the tape recorder and the automatic slide projector. These two units are used together to present an illustrated talk with a minimum of effort.

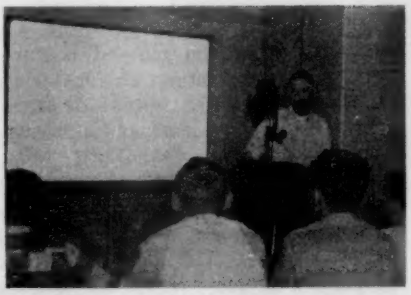


FIGURE 2.—Use of the graphic viewer in lecturing to trainees.

Graphic Viewer

The graphic viewer is used to project drawings onto a screen. This unit is placed in front of the class (Figure 2) and to one side of the instructor. The picture is then projected onto the screen over the instructor's shoulder. The instructor is thus able to face the class and can readily manipulate the drawings. For example, through the use of over-lays the operation of a sludge digester can be vividly explained. The operators can see (a) the actual piping, (b) the sludge being pumped to the tank, and (c) the production and removal of gas. Other units can be presented in the same way.

The instructor can make a sketch, work out mathematical problems, fill a table with data, and project his work to the screen in easy steps; all with the use of this projector. It is the equal of blackboard presentation and superior in many instances.

In-Plant Training

Actual in-plant training is scheduled in between the lecture courses, so that the student can put to practical use some of the material obtained from the instruction. The students actually follow an operator through a typical day's work. Where possible, depending on the number of operators to be instructed, the student works with the operator until he is thoroughly familiar with his duties.

Operation Manual

A plant operation manual is furnished to each operator. This material was prepared by the sewage disposal section supervisory staff and presents in easily understandable text, diagrams and pictures, the principles of sewage treatment plant operation at the Cincinnati works.

Periodically a foreman checks with the trainee to see whether he understands the manual. Additional instruction and in-plant training follow. At the end of the instruction period, when the trainee is ready to be assigned a full-time position, he is given a series of short examinations. These exams serve as checks on the training program and what the trainee has learned.

Conclusion

Refresher courses are given to all operators, depending upon experience. Recent graduates of the training program receive a refresher course every two months until they receive their "C" operator's certificate from the state department of health.

All personnel are encouraged to take correspondence courses, to become registered or certified as engineers or operating personnel, whichever is their specialty.

It is sincerely believed that the training program used at Cincinnati is effective and necessary whether 4 to 5 or 30 to 40 new operators are to be trained. It has been found that the program can be continued effectively on a reduced scale for those individual operators coming to the plant as replacements after the plant is in operation.

Proper training of operators produces the following results:

1. An operator who knows why he is doing certain operations.
2. Relieves supervisory personnel from the task of constant detailed checking.
3. Makes for better cooperation between employees and between the operating staff and the supervisory staff.

SMALL PLANT OPERATOR TRAINING*

By Max B. Phillips

Superintendent, Sewage Treatment Plant, Bryan, Ohio

Small sewage or industrial waste treatment plants, such as those staffed by a superintendent or chief operator and fewer than 10 other employees, should consider training programs and related activities as important a part of their employee-public relations program as the larger municipal plants. The employer of sewage and industrial waste treatment personnel, whether a municipal government, sanitary district, private utility or industry, has four principal interests in treatment plant operation:

1. The proper use and maintenance of the facilities.
2. The efficient performance of the treatment units.
3. The economy of the operations.
4. A satisfactory employee policy.

The training of operating personnel may present the greatest problem. Generally, the operation of the treatment plant is not understood by most employers. As a result, the employer usually bases his opinion on the plant needs on the information furnished by the superintendent or chief operator.

Initial Operation

The needs of the treatment plant should be determined and a proposed

* Presented at the 1956 Annual Meeting, Ohio Sewage and Industrial Waste Treatment Conf.; Cleveland, Ohio; June 13–15, 1956.

operating schedule prepared before the plant is placed in operation. The employer can ascertain these needs from the designing engineer, with the assistance of the sanitary engineering section of the state department of health. A proposed work plan should be made of the actual hours of operation, time off, shift changes and work schedules. The extent of the laboratory analysis, as local conditions dictate, should be determined.

A great deal depends on the initial analysis of the treatment plant needs. Since the plant will become a permanent part of the utility or industrial waste system, planning should be on a long-term basis, and a training and instruction program to provide the proper operation and maintenance is of utmost importance.

The method of training and instruction depends on the particular situation. In the very small plant, the contractor will assist the operator in getting started. Sometimes, the equipment supplier may have as part of his contract the instruction of operators. Larger plants will employ an experienced operator who can properly plan a training program.

In any case, the trainee operators should be on the job during the final phases of construction. This provides them with an opportunity to be present when the responsibility is still with the contractor. The workmen can be a source of information and confidence to the beginner. Quite possibly, some false concepts may be picked up in this association, but these can be corrected later. Most important, the operators can learn plant detail and observe what is going on.

For the smaller plants, the final two weeks of construction should be the minimum time allotted to this type of instruction by the contractor. All operators should work the same hours and be given an equal opportunity to learn. This training can be adjusted by the superintendent or other official so that by the final acceptance date definite shifts and duties can be assigned and the tentative schedule begun.

Working drawings of the treatment plant, and bulletins and illustrations of all the equipment should be obtained from the contractor and supervising engineer. Excuses should not be accepted for the loss of equipment bulletins, and immediate efforts should be made to obtain replacements. This material should be filed permanently for future use and reference. It is advisable for the superintendent or senior operator to familiarize himself with the contents of the bulletins and drawings.

Equipment Supplier

When an equipment supplier provides instruction in the use of particular pieces of equipment, the initial orientation of the trainee operator is greatly enhanced. Usually the instructor is well qualified and specializes in the equipment or processes made by his company. It depends on the individual trainee as to how fast and how much he will learn.

A good instructor will discuss thoroughly each piece of equipment, its place in the treatment plant, what to expect in the way of operation, the difficulties that might arise, and the correct methods for making adjustments. Actual demonstrations of the equipment will aid the trainee. The trainee will be given the opportunity to make adjustments himself and, of course, to ask questions.

This type of instruction should be scheduled for a minimum of three weeks. The average operator with any inclination can be given a good start toward satisfactory operation in this manner. However, he should have sufficient knowledge to proceed practically alone in self-study and practice.

Technical Supervisor

The technical supervisor, as known in Ohio, is a qualified treatment plant

operator employed temporarily on a part-time basis to instruct the inexperienced personnel at a new treatment plant. His duties are usually outlined by the state health department and he guides the plant through its first year of operation.

Probably the supervisor will have to spend more time at the plant during the first year of operation, perhaps a visit once each week. He will assist in the establishment of a training program to correct operating problems and increase the knowledge of the operators. Monthly reports will be made by the supervisor to the state health department, the employer and the operating staff of the treatment plant.

The supervisor will insure that recommended procedures are followed. He will check on the scope and effectiveness of the laboratory schedule, in accord with the requirements of the state health department and the employer. As operational problems arise the supervisor will explain the cause and the reason for any changes recommended.

The use of laboratory equipment and the scheduled tests will be demonstrated. The trainee always should understand why something is done. When one operator becomes proficient in laboratory procedure he can instruct other personnel to the extent advisable and as time permits.

Occasionally the technical supervisor method of operator training does not proceed as well as intended. Often the operator does not want to learn or possibly the supervisor does not have the ability to instruct. Sometimes the employer does not realize the benefit the treatment plant can derive from this service.

The employer, when setting up an operating schedule which calls for a technical supervisor, should be certain that at least one operator will be employed at the treatment plant who will be able to attain certification, so that in the proper time the temporary supervision will not be necessary. Technical supervision should be regarded as a method to train and instruct the staff so that the plant eventually will be a self-operated unit. Outside supervision was never meant, in most instances, to be a permanent operating necessity.

When a schedule of operation has been established, each operator will have to be instructed in the particular duties of the shift and the routine of inspections which will probably be uniform on all shifts. However, certain special duties may be assigned to particular men, such as lubrication of motors and equipment. Other shifts will handle work that regularly occurs during the shift. Under ordinary circumstances, there should be little maintenance in this initial period; therefore, when each shift routine can be competently carried out by the operator, other tasks may be assigned.

Eventually, the personnel should take care of all maintenance work in the plant, with the exception of some plumbing and electrical work. Pump overhauling, hauling sludge, painting, and cleaning jobs can be assigned so that these tasks will be performed.

When a daily work sheet is used, a brief report should be made by each operator, and any unusual occurrences or jobs done can be noted. This is a good reference for the operator following on the next shift and also serves as a work history.

In most plants the operational changes on a day-to-day basis are small. The superintendent can establish what changes may be made by the individual, such as rate of waste activated sludge, mechanical aeration periods, chemicals fed, or rates of sewage flow. This freedom increases the operator's confidence and interest in the operation of the plant. When the operator training has progressed to this point, it permits the superintendent to devote more time to other administrative duties.

Certification

Assuming the training of operators in their general work has progressed to where they can efficiently and confidently carry out the operational duties expected of them, assistance should be given to those operators interested in being certified by the state health department. With some assistance along the lines of what can be expected in the annual examinations, most operators that are so inclined can obtain a Class "C" certificate. Further advancement depends on the individual, but generally the training for higher certification can be obtained in the home plant.

Certification is not always a standard of quality. Through personal preference an otherwise capable operator may not choose to take the examination. When certification is not mandatory for the operation of the treatment plant the operator should not be compelled to take the examination.

Short Courses

In the very small treatment plant, the operator can only advance so far alone in his efforts to learn practice and procedure. Unless he can get assistance, he may find himself confronted with numerous dead ends which might tend to discourage him.

Recognizing this need, the state health departments sponsor short courses. These courses cover the requirements for the different examinations, and attendance earns credit toward an earlier certification. Instruction in procedures that are not available in the home plant is one of the principle reasons for attending short courses.

Recently some state health departments have instituted a series of monthly letters for interested operators to assist them in their education. These letters cover various subjects and include typical problems.

Meetings

Regional and state meetings afford an opportunity for operators to visit and gain information through discussion of their problems. At these gatherings the operator finds an interested audience, talks shop, listens to the presentation of informative papers, and obtains new ideas which he cannot obtain at home. Frequently he learns about a solution to a particular problem of his developed by other operators with a similar situation.

Other Educational Aids

Every treatment plant should have at least one membership in the state or regional sewage and industrial wastes association. Copies of several technical magazines and journals should be available at the plant and a reference shelf maintained. Each reference shelf should include copies of the available text books on the subject of sewage and industrial waste treatment and equipment maintenance.

The advertisements in the magazines should be read. Frequently an advertiser offers booklets, illustrated bulletins or other material of interest to the operator. Most equipment manufacturers are glad to answer inquiries about their products or questions on operating problems, such as the use of special paints or chemicals.

Conclusions

It should be appreciated that a new operator approaches his job with a sense of insecurity and a feeling of strangeness concerning the treatment plant and the work to be done. Many workers quit their jobs because of a dissatisfaction that could have been cleared up or prevented by the superintendent.

A high turnover rate among employees is an unsatisfactory condition. Steady employees are most happy when work conditions are consistent or can be anticipated sufficiently in advance so that the employee can make

necessary adjustments. As part of the over-all plant training program the following points make for a better adjusted employee:

1. A job fitted to individual qualifications as much as possible.
2. Introduction to fellow employees.
3. Explanation of special rules and policies.
4. Explanation of working hours and shift changes.
5. Instruction as to duties.
6. Acquaintance with the order of authority (chain of command) and who to see with respect to work instructions or grievances.
7. Encouragement should be given to each deserving employee and constructive criticism offered when appropriate.
8. Each employee should receive periodic personal attention.
9. Opportunity for advancement should be offered when deserved and when possible.

The training available to the small plant operator is varied. Many operators have been instructed in one or more of the programs mentioned. Each can strive to learn more and to help other operators. The need for in-plant and profession-wide training is more important today than at any other time. There will continue to be a need for well-trained operators and good training programs.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"You're only young once—but you can stay immature indefinitely."—*Anon.*

Attention operators! It will be appreciated if copies of the annual reports of both large and small sewage and industrial waste treatment plants are sent to the Federation office for abstracting in this section of the Journal. Please direct annual reports to: The Operator's Corner, Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

Report of the Kenosha, Wis., Sewage Treatment Plant for the Years 1954 and 1955 *

By Frank I. Vilen, *Superintendent*

General

Kenosha is a typical industrial city with an estimated 1955 population of 58,000 and is engaged principally in metals fabrication. Industrial process wastes are estimated to make up 28 per cent of the average daily sewage flow. The combined sewer system contributes approximately 38 per cent of the average daily flow as storm water and infiltration. The remaining 34 per cent of the flow can be considered as sanitary sewage.

All new sewers are being constructed as separate sanitary or storm sewers. Plans have been prepared for diversion of the flow from Lincoln Park Lagoon, which discharges into a combined trunk sewer, to a new storm sewer. This lagoon serves as a catchment basin for a considerable drainage area. Weir measurements made in 1954 in-

* For last previous extract see This Journal, **27**, 1, 105 (Jan., 1955).

dicated discharges to the trunk sewer ranging from 400 g.p.m. during dry periods to a high of 6,000 g.p.m. during storm conditions. When this diversion is completed it will greatly reduce the load at the treatment plant which now averages 40 per cent above the design flow. An extension of sewer service to a residential area adjacent to the city has been arranged.

Industrial wastes did not present any problems, and excellent cooperation with the various industries was enjoyed.

Treatment Units

The average daily sewage flow to this primary treatment plant increased from 13.62 m.g.d. in 1953 to 14.37 m.g.d. in 1954. This increase was due to the near-record rainfall of 38.75 in. The following year (1955) the rainfall was near normal at 24.83 in. and the flow decreased to 13.82 m.g.d.

Although minute quantities of toxic materials are received from the industries, digestion operation has continued good. The principal toxic metal is copper, and constant laboratory checks are made to ascertain the copper content in the digester. The copper accumulation in the digesters reached a low in 1955 when only 0.25 per cent, as dry solids, was measured.

Two sets of additional heating coils were installed in both digesters in 1954 to improve the digester temperature. These coils were supported on angle iron A-frames and extended across the digesters at about the quarter points on the digester diameter. This inexpensive installation (approximately $200 per digester) has more than paid for itself in better gas production. It is now possible to maintain an average sludge temperature of 90° F. during all seasons, as compared to an average of 82° F. in 1953.

Based on net digester capacity, the tabulation of gas production rates and loadings for the past four years is:

Year	Solids (lb./day/cu. ft. dig. cap.)		Gas	
	Total	Volatile	(cu. ft./lb. of vol. solids)	(cu. ft./ capita)
1955	0.107	0.066	7.11	0.66
1954	0.098	0.059	6.98	0.60
1953	0.111	0.066	6.95	0.70
1952	0.107	0.062	5.94	0.56

Gas production per pound of volatile solids added is computed on the basis of total volatile matter in the sludge as measured by standard laboratory procedure. Considerable grease and oil, both mineral and organic, form a substantial part of the total volatile content of the sludge. Greases averaged 19.5 and 25.1 per cent in the raw sludge and 9.8 and 11.5 per cent in the digested sludge in 1954 and 1955 respectively. Assuming that the 11.5 per cent remaining in the digested sludge is grease which cannot be considered as "gas-producing" volatile matter, the "adjusted" gas production for 1955 would be 8.05 cu. ft. per pound of volatile matter added to the digesters.

Of the total gas produced, approximately 94 per cent was utilized by the gas engines for pumping sewage and heating the digesters and the plant structures. At standard rates, the gas produced had a fuel value of approximately $10,000.

The most significant development in plant operation was the elimination of seasonal labor for sludge removal. A light tractor with a front-end loader was purchased in 1954 to permit the removal of sludge from the drying beds by one man. Experience to date indicates an annual saving of about $2,000 in labor costs and that one employee can remove the sludge as effectively as with the hand labor and dump car system previously used.

An area in the vicinity of the sludge drying beds has been developed to provide a sludge drying and storage capacity equal to 50 per cent of the

TABLE I.—Summary of Operating Data, Kenosha, Wis., Sewage Treatment Plant for 1954 and 1955

Item	Average 1954	1955
Rainfall (in.)	38.75	24.83
Sewage flow (m.g.d.)	14.37	13.82
Pop. served (est.)	56,500	58,000
Susp. solids (p.p.m.):		
Influent	130	127
Effluent	56	52
Reduction (%)	57	59
Sett. solids (ml./l.):		
Influent	1.69	1.5
Effluent	0.15	0.08
Reduction (%)	93	95
pH:		
Influent	7.4	7.5
Effluent	7.4	7.5
B.O.D., 5-day (p.p.m.):		
Influent	100	98
Effluent	52	57
Reduction (%)	48	42
Chlorine demand (p.p.m.):		
Influent	7.3	6.7
Effluent	4.3	4.5
Raw sludge data:		
To primary (gal./day)	7,550	6,860
To secondary (gal./day)	6,450	6,860
Solids (%)	7.71	8.3
Dry solids (lb./day)	8,640	9,410
Vol. solids (%)	60.4	62.5
pH	6.7	6.7
Grease (%)	19.5	25.1
Dig. sludge data:		
Solids (%)	14.5	15.2
Dry solids, total (tons)	426	560
Vol. solids (%)	40.6	42.2
Grease (%)	9.8	11.5
Sludge gas data:		
Gas produced, total (m. cu. ft.)	13.05	15.3
Per m.g. sewage (cu. ft.)	2,480	3,130
Per lb. dry sol. (cu. ft.)	4.14	4.45
Per lb. dry vol. sol. (cu. ft.)	6.98	7.41
Per cap. daily (cu. ft.)	0.6	0.66
Supernatant:		
Dry solids (%)	0.35	0.43
Vol. matter (%)	52.7	52.8
Operating cost ($):		
Total	88,010.48	82,665.12
Per m.g.	16.73	16.40

old drying bed capacity. Sludge is pumped to this area during the winter and removed during the summer.

Equipment maintenance continued near normal with the usual worn parts replacements and preventive maintenance.

Operating Costs

Operating expenditures were slightly less in 1955 than for the previous year because the 1954 costs included a works program to alleviate a local unemployment situation.

Capital improvements, in addition to the tractor for sludge removal and some laboratory equipment, included new concrete walks, fencing, a lawn sprinkling system and a concrete block storage building. Approximately 3.1 acres of swamp adjoining the plant grounds were filled in, seeded, and

planted with shrubbery as part of the labor relief program in 1954. The plant sinking fund receives $10,000 to $11,000 each year.

One additional employee was added to the staff of ten, primarily to operate the tractor for sludge removal.

Public Service

A clean plant with attractive grounds continues to pay dividends in good public relations. Many visitors, both local and out-of-town, visit the plant each year. An unusual event in 1954 was a picnic lunch on the plant grounds by the Kiwanis Club.

The providing of local weather information to the newspaper, radio station, and fuel oil dealers has continued. The plant serves as a cooperative weather station for the U. S. Weather Bureau. A new service feature initiated in 1954 is a daily pollen count during the hay fever season.

Copies of the annual reports are mailed to approximately 30 municipalities, libraries and others interested.

The operating data for 1954 and 1955 are summarized in Table I.

Annual Report of the Oceanside, Calif., Sewage Treatment Plant for the Year 1954*

By E. O. Sampson, *Chief Operator*

General

Sewage flow during 1954 decreased 12 million gallons compared with the previous year. This reflected the reduced connected population obtaining from the movement of troops out of the nearby Marine base, which occurred during the last third of 1953. Except during the two months of peak tourist trade, the estimated connected population is 15,000, down from the peak of 22,000. The treatment plant operated at 65 per cent of capacity.

Two new pumping stations were placed in operation but the increased flow did not add appreciably to the total flow. The attractiveness of the oxidation pond to adventuresome children emphasizes the need for a protective fence around the sewage plant grounds.

Oxidators

The secondary oxidator was used as the primary while the latter was cleaned and painted. Following this maintenance work, the primary oxidator was used as a clarifier without aeration and the secondary unit was removed from service. The treated effluent was recirculated continuously during the year. The sleeve on the effluent discharge was removed and the effluent splashed into the headworks without a noticeable increase in sulfide odor.

Average removals of suspended solids and B.O.D. were lower than in 1953, being 77.1 and 58.8 per cent respectively. The increase in effluent B.O.D. is attributed to the discharge of digester supernatant at the influent to the plant.

Raw sludge quantities decreased and sludge pumping time was reduced 15 per cent. The policy of not pumping sludge at night is still operating satisfactorily. Algae from the recirculated oxidation pond effluent is carried through the oxidator and imparts a green color to the final effluent.

Oxidation Pond

The five-acre oxidation pond was completed in August 1954 and placed in operation after seeding with water from a nearby treatment plant pond.

* For last previous extract see This Journal, **26**, 8, 1043 (Aug., 1954).

TABLE II.—Summary of 1954 Operating Data, Oceanside, Calif., Sewage Treatment Plant

Item	Average
Rainfall (in.)	11.64
Population, connected (est.)	16,000
Sewage flow (m.g.d.)	1.32
Maximum (m.g.d.)	1.44
Total (gal.)	482
Raw sludge (g.p.d.)	5,669
Solids (%)	5.36
Suspended solids (p.p.m.):	
Influent	289
Effluent	66
Removal (%)	77.1
B.O.D., 5-day (p.p.m.):	
Influent	293
Effluent	121
Removal (%)	58.8
Sulfides, effl. (p.p.m.)	0.54
Chlorine used:	
Pounds per day	248.7
Pounds per m.g.	183
Total (lb.)	44,767
Primary digester:	
Temp. (°F.)	93.9
pH	7.05
Vol. acids (p.p.m.)	360
Alkalinity (p.p.m.)	3,300
Solids (%)	1.85
Gas produced (1,000 c.f./day)	24.15
Natural gas used (1,000 c.f./day)	0.11
Oper. and maint. cost ($):	
Total	21,424.35
Per m.g.	46.35

Operation of the pond has been described previously.*

Sludge Digestion

For the first time since the treatment plant was placed in operation (1950) the primary digester "took off," producing an excellent volume of good quality gas. Heavy foaming occurred in the primary and, to some extent, in the secondary. Control was maintained by frequent hosings with water and the discharging of 50 per cent of the raw sludge to the ocean outfall sewer during the first two months of digester activity.

Volatile acids averaged 360 p.p.m., a decrease from an average of 3,678 p.p.m. the previous year. The pH improved to pH 7 and the alkalinity averaged 3,300 p.p.m. The use of natural gas was discontinued and the sludge heater was operated on digester gas with a material saving in cost for fuel. Digester temperature in the primary was maintained at 94° F. and the secondary operated at 88° to 82° F. Gas production averaged 12.4 cu. ft. per pound of volatile matter.

Only 327,360 gal. of digested sludge were hauled away in tank trucks for purposes of fertilizing ranch land. Scum on the primary digester had practically disappeared by the end of the year although the secondary digester had scum to a considerable depth. Indications are that the secondary digester is in need of cleaning because the bottom suction line becomes plugged when sludge is withdrawn by gravity.

* See THIS JOURNAL, **27**, 12, 1410 (Dec., 1955).

Chlorination and Odor Control

Odors were held under control through the use of an odor-masking compound in the exhaust ventilating system at the headworks, and the prechlorination of the influent. (All units at the plant are housed.)

The sulfide content of the sewage increases appreciably during warm weather and makes adequate odor control imperative. Usual practice is to chlorinate the entire effluent, including that which is recirculated. Chlorination of the final effluent on the downstream side of the flow meter is also practiced to maintain a .1 to .2 p.p.m. residual. When the sulfide content increases substantially it is necessary to chlorinate the influent directly. A total of 44,767 lb. of chlorine was used during the year.

The drip system of applying the masking agent was changed in favor of an atomizer constructed with a small air compressor. Operation was greatly improved.

Miscellaneous

Miscellaneous maintenance included cleaning and painting the primary oxidator, replacing corroded gas collecting piping to the primary digester, and various overhaul and routine maintenance tasks.

Although labor costs increased due to automatic salary increases, the total operating cost of the plant decreased. Chemical costs were lower because of a one-third reduction in chlorine used. The saving in fuel gas for digester heating amounted to $400.

Construction of the oxidation pond was considered as a capital improvement expense.

Operating data for 1954 are summarized in Table II.

PUMP SPARE PARTS *

A pump, like any other piece of machinery, is subject to wear and will need to have some parts replaced after a period of operation. The frequency of repair, as well as the number of parts to be replaced, is determined largely by the severity of the service. Wear is affected by the properties of the liquid such as temperature, corrosiveness and abrasiveness, as well as pump fit, suction conditions and the adequacy of the installation. Obviously a pump used for only a few minutes a day on clear water will be subject to less wear than a pump operated 24 hr. a day on hot, caustic slurry. However, even the cold water pump eventually will require some repairs.

Some parts should be on hand at all times, since they must be replaced as soon as they become excessively worn or fail. Parts that are in this class include bearings, bearing shells, shafts and mechanical seals. Other parts must be replaced when worn, but it is usually possible to use the pump on a limited basis until new parts can be obtained. Such parts normally include sleeves, impellers, casing wearing rings, sideplates, glands and possibly casings on certain liquids. Limited operation may be much better than no operation, but it may also result in loss of valuable production and excessive maintenance. As an example, the casing wearing ring may become worn, increasing the clearance and the internal leakage or recirculation back to the suction side of the impeller. This reduces the capacity pumped until the pump may be unable to produce a sufficient flow to maintain rated production.

Obviously, when pump parts become badly worn they should be replaced to restore the pump to first class condition. With a well organized sys-

* Condensed from *Gould News*, July–Aug., 1956.

tem of preventive maintenance, it is possible to detect and anticipate future parts requirements. It is necessary that the specific parts which should be on hand at all times, be determined for each installation. Lists of recommended spare parts for pumps under normal conditions of service are included in most instruction books. These lists serve as a guide and must be tempered by the specific conditions under which each pump operates. These conditions include the severity of service, and the cost if the pump service is interrupted while the replacement is made.

The availability of spare parts should also be considered carefully for each pump. A complete set of spare rotating parts should be kept on hand if the pump is essential to plant operation.

Pump spare parts can be considered as a free insurance policy. The premium is paid when the parts are bought but a dividend is obtained in the form of minimum delay in return of a pump to service. It is suggested that the spare parts inventory be reexamined and the proper parts obtained before a pump failure occurs.

TIPS AND QUIPS

Monthly Instructional Letters

A series of monthly letters to water and sewage plant operators was inaugurated in Ohio in March 1956 under the auspices of the Ohio short school sponsors. Associate Professor Kenneth W. Cosens of Ohio State University is the letter writer.

Purpose of the letters is to help the operators review the mathematics and chemistry of plant operation. The present general plan is to devote approximately six months to mathematical principles and computations, and then follow this with six months on chemical principles and computations of importance to water and sewage plant personnel. Each letter covers a different subject by presenting the basic principles and necessary definitions. These are supplemented with example problems, followed by a group of problems to be worked. Answers to the problems are included in the next letter.

The letters are financed at present by the sponsors. Response has been most gratifying, and apparently the letters serve a real need among plant operators.

Further information can be obtained from Professor Cosens, Department of Civil Engineering, Ohio State University, Columbus 10, Ohio. Or better still, organize monthly letters to operators in your own state through the facilities of your Sewage and Industrial Wastes Association, health department or operators association.

Muralization

The Coral Gables, Fla., sewage treatment plant is unusually attractive. Colorful murals and abstract designs have been painted on the large expanses of exposed concrete such as digestion tanks. These designs are visible from the main highway which passes near the treatment plant, and have evoked considerable interest in this facility which provides the citizens of Coral Gables with modern sewage service.

Acid Wastes Trucked Away

Stream pollution has long been of real concern in the highly industrialized valleys near Pittsburgh. Some years ago the steel companies were faced with finding a way to dispose of increasing volumes of spent pickling acids without violating the law. Rather than invest in waste

treatment facilities themselves many plants began using the services of Industrial Wastes Inc., Beaver Falls, Pa.

Industrial Wastes Inc. operates a fleet of tank trucks to haul away spent acids. The trucks range as far as 120 miles from their two neutralizing plants in the Youngstown-Pittsburgh area. Currently they are handling about 2.5 million gallons of acid wastes monthly. After treatment this liquor is dumped into abandoned quarries at the neutralization plant sites.

Paint Bulletin

A new manual worth reading has been published by the Plastic and Synthetics Division, U. S. Stoneware Company, Akron 9, Ohio. Bulletin No. 760 presents useful painting data on the complete line of Tygon protective coatings and related primers. Surface preparation, priming, application methods and maintenance instructions are presented for the different paints. Tables outline the use and application of these paints on various surfaces. Of special interest is a section on hot spray painting and its important features.

Foot Comfort

Cold wet weather heralds the season of wet feet and such illnesses as colds, flu, pneumonia or worse. Although biological medicines and improved medical care have improved the recovery rate from such illnesses, the lost-time factor and general effect on employee health are still to be reckoned with. As part of a good employee health program, the following can aid materially in keeping feet dry and reducing the incidence of illness:

Rubbers

Work rubbers that slip over wide-last safety shoes and have high tops give extra protection against splashes. Rubbers molded in one-piece from neoprene are easy to clean and resist deterioration on contact with oil, grease, acids or other chemicals.

Special Leather Shoes

A solution to the problems associated with wearing rubbers or overshoes—hot, stuffy feet and the inconvenience of putting the rubbers on and off, is to wear work shoes treated with one of the special silicone products for leather. These products, when used in tanning the leather, provide lasting water repellency without clogging the pores in the leather through which the foot breathes.

Socks

An ample supply of clean dry socks is one of the best remedies for wet feet. Every employee should have extra socks on hand at the treatment plant and be encouraged to change socks and shoes promptly when they become soaked.

A few common sense precautions together with good health habits will reduce winter illnesses caused by wet feet and chilling.

Yakima Valley (Wash.) Operators

An interested group of sewage and industrial waste treatment plant operators have organized a local section of the Pacific Northwest Sewage and Industrial Wastes Association. Four to six meetings each year with a guest speaker are planned to exchange information and discuss operation problems.

Local sections of the Member Associations are not new and they serve a very useful purpose, provided the membership appreciates the need for encouraging active participation in the Member Association and Federation activities.

News and Notes

Of Persons and Activities in the Field of Hydrowastes

Adolf Rumpf, director-elect of Abwassertechnische Vereinigung, German Member Association, died recently at Michelbach, Nassau, Germany. He was a well-known and respected engineer, and director of the Passavant-Werke (Public Works) in Michelbach. He presented a paper on high-rate trickling filters in Germany at the 1955 Meeting of the Federation.

Havens and Emerson, Consulting Engineers, recently announced that **Noel S. Chamberlain**, former Industrial Consultant, Technical Services Division, Wallace and Tiernan, Inc., has joined their New York staff.

Walter L. Picton, Deputy Director, Water and Sewerage Industry and Utilities Division, BDSA, Washington, D. C., has been designated by the U. S. Department of State as the United States specialist on water utilities at a conference of the public utilities working groups that report to the NATO Civil Defense Committee.

Alexandria, Va., recently placed in operation a high-rate trickling filter plant under the direction of **James J. Corbalis, Jr.**, Engineer-Director, Alexandria Sanitation Authority. **Sam W. Shafer**, former Assistant Superintendent, Mill Creek Sewage Works, Cincinnati, Ohio, is the Superintendent.

Director **C. S. Anderson** of the Canadian Member Association underwent cardiac surgery the latter part of August.

Recent additions to the ranks of the consulting engineers include **Walter H. Jollie**, former Sanitary Engineer, Illinois Department of Health, who has become associated with Baxter & Woodman, Civil and Sanitary Engineers, Crystal Lake, Ill.; **Walter T. McPhee**, formerly with Malcolm Pirnie Engineers, who has joined Weston, Eckenfelder and Associates, Newtown Square, Pa.; and **Norman E. Jackson**, former Chief Engineer, Dalecarlia Filter Plant, Washington Aqueduct Commission, Washington, D. C. who is now with Camp, Dresser & McKee, Consulting Engineers, Boston, Mass.

George E. Flower, Commissioner of Sewage Disposal, Cleveland, Ohio, has retired after 43 years of public service with the city. Prior to succeeding A. W. Elms in 1950 as commissioner, he was Superintendent of the Cleveland Southerly Works.

John R. Snell and **Waldo I. Kenerson** announce the formation of Michigan Associates, successor to John R. Snell and Associates. Both Snell and Kenerson are former faculty members of the Civil Engineering Department at Michigan State University. At present Dr. Snell is on a three-month visit to the Orient under the auspices of WHO.

A Federation Past-President, **Francis S. Friel**, Consulting Engineer, Philadelphia, Pa., has been elected a Vice-President of the American Society of Civil Engineers.

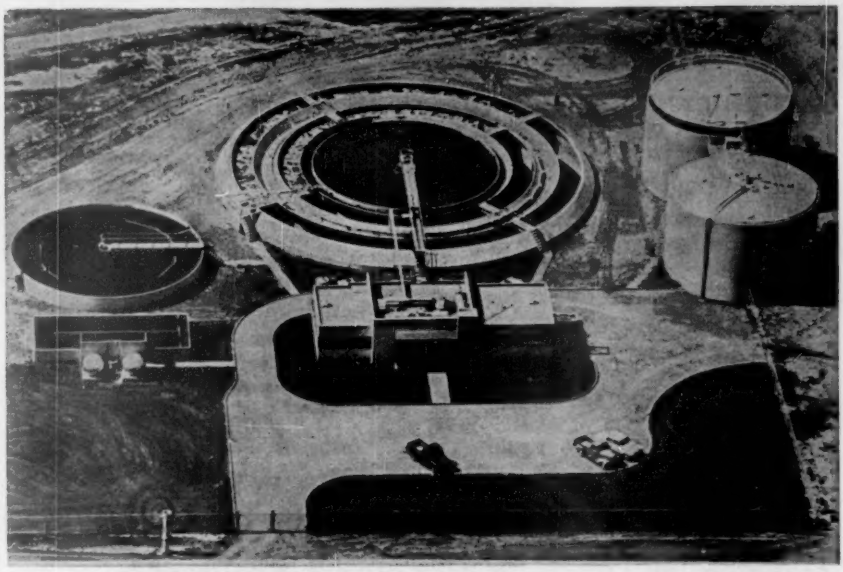
Harvey F. Ludwig, Sanitary Engineer Director, USPHS, resigned recently to accept a position with Hycon Aerial Surveys, Inc., Pasadena, Calif. He was active in strengthening the professional engineering and research activities of the Public Health Service.

Professor **Robert S. Ingols**, Georgia Institute of Technology, is on sabbatical leave to fill a Fulbright Lectureship at the Milan Polytechnic Institute, Milan, Italy.

Herbert P. Orland, former Associate Editor of *Sewage and Industrial Wastes* and more recently with Scranton Publishing Co., is now Editor, Highway Research Board, Washington, D. C.

James G. Walker, New York Area Sales Manager for the Johns-Manville Pipe Division, has been appointed Northeastern Regional Sales Manager.

H. Heukelekian, Professor at Rutgers University, has returned from a three-month WHO assignment to Israel where he was a consultant on various sanitary engineering problems.



Engineers—Currie Engineering Company

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Proceedings of Member Associations

MICHIGAN SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The Michigan Sewage and Industrial Wastes Association held its 31st Annual Conference at the Whitcomb Sulphur Springs Hotel, St. Joseph, Mich., on May 14–16, 1956. The total registration of approximately 310, including 60 ladies, was an all-time attendance record.

The first feature of the program was a panel presentation entitled "The War on St. Joseph River Pollution," which covered the history of pollution growth and control on this interstate river. Inspection of the sewage treatment facilities owned and operated jointly by the cities of Benton Harbor and St. Joseph followed.

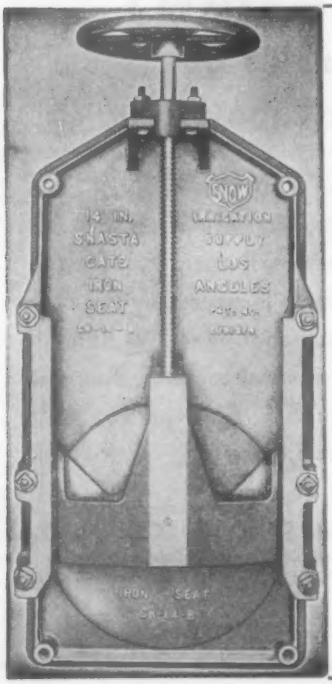
An informative, thought-provoking panel discussion on "Controlling Toxic Waste Discharges to the Clinton River," held the spotlight on the second afternoon. This panel was moderated by Sam Porter of McNamee, Porter and Seeley, Consulting Engineers, Ann Arbor. Participants represented the state health department, the city of Pontiac, and the industry involved.

In concurrent sessions the industrial waste and sewerage groups heard the following papers:

"Insurance for Sewerage Works and Workers," by J. N. Poel, City Clerk, Grand Haven.

"New Developments in Biological Treatment," by A. H. Ullrich, Superintendent of Water and Sewage, Austin, Texas, A. E. Becker, Jr., and

(*Continued on page 468a*)



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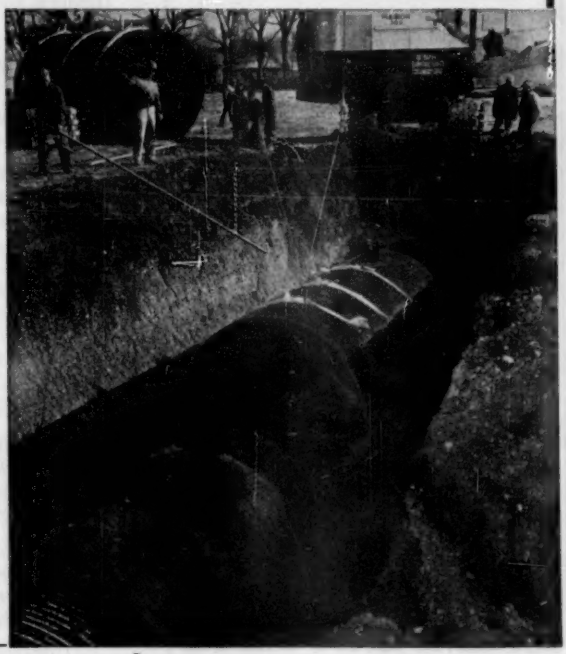

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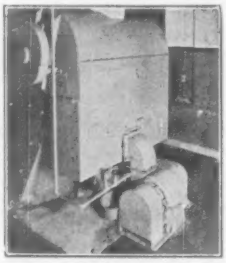

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"Air Pollution Aspects of Sewage Plant Operations," by Benjamin Linsky, Bureau of Smoke Inspection and Abatement, Detroit.

"Pitfalls of Plating Waste Treatment," by N. S. Chamberlain and H. B. Snyder, Wallace & Tiernan, Inc.

"The Use of Bioassays in the Safe Disposal of Toxic Wastes," by Clarence Tarzwell, Chief, Aquatic Biology, USPHS, Cincinnati.

"Methods of Analysis of Heavy Metals and Phenols," by Russell Krueger, Sanitary Chemist, Michigan Water Resources Commission, Lansing.

In addition to the technical sessions, a training session for sewage treatment plant operators was conducted by the Michigan State Department of Health. Sampling procedures and techniques were discussed and demonstrated.

The concluding session was devoted to round-table discussions on chlorinator operation and chlorination, and sludge digestion.

Officers elected at the annual business meeting were:

President: Michael A. Groen, Dearborn.
1st Vice-President: Homer J. Hayward, Ann Arbor.
2nd Vice-President: Robert J. Peterson, Birmingham.
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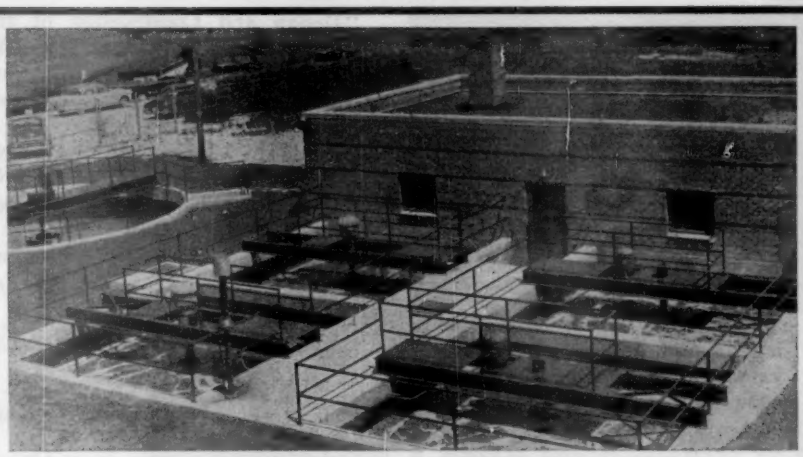
The 1956 Annual Conference of the Maryland-Delaware Water and Sewage Association was held at the Willard Hotel, Washington, D. C., on May 10–11, 1956. Registration totaled slightly more than 160.

Featured papers of interest to sewage works personnel included:

(*Continued on page 470a*)



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"Design and Construction of the Sewerage System at St. Michaels, Maryland," by Francis S. Friel and R. A. Falciani, Albright and Friel, Philadelphia, Pa.

"Operating Problems of a New Sewage Treatment Plant," by W. C. Henry, Superintendent, Sewage Treatment Plant, Wilmington, Del.

"New Developments in Pumping Sewage Solids," by Fred Stuart, Jr., Stuart Corp., Baltimore, Md.

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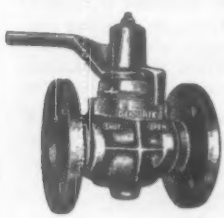

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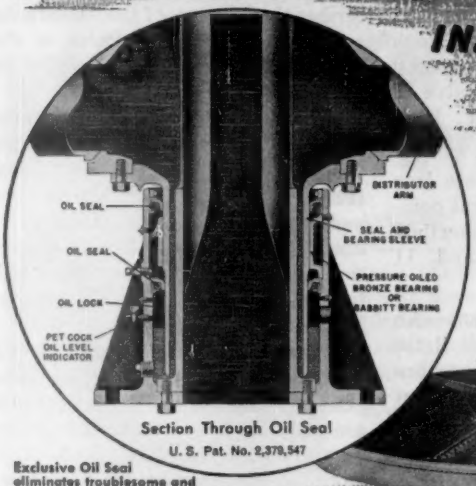

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Industrial Waste Equipment—An 8-page pocket-sized booklet, Bulletin No. 315-111, attractively describes screening and clarification equipment under the question "Why Industrial Waste Treatment?"—Chain Belt Co., Milwaukee 1, Wis.

Flex Valves—A precision built valve with a flexible inner valve sleeve of rubber or synthetic materials is available for use in abrasive service. The valve controls flow by a squeezing action of the flexible sleeve.—Farris Flexible Valve Corp., 710 Commercial Ave., Palisades Park, N. J.

Chlorine Gas Feeder—A volumetric chlorine gas feeder, equipped with automatic safety features and reportedly low in cost, is described in 4-page Bulletin 840-L23B.—Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.

Mechanical Flowmeter—An evenly graduated mechanical flowmeter is described in Specification Sheet 242-2.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Chemical Pumps—A complete line of small, rotary displacement and centrifugal pumps for chemical service is fully described and illustrated in a revised bulletin.—Eco Engineering Co., 12 New York Ave., Newark 1, N. J.

Comminutor—Bulletin 5100-B describes the features of the "Griductor" comminutor which operates to shear and cut sewage solids.—Infilco Inc., Tucson, Ariz.

Settled Sludge Remover—Bulletin No. 315-81 describes the "Unitube Tow-Bro Sludge Remover," which features an improved simple, inexpensive, collector arm, thereby eliminating the expensive nozzle construction of conventional Tow-Bro Collectors.—Chain Belt Co., Milwaukee 1, Wis.

Nuclear Science Instruments—Various types of monitoring equipment (Geiger and scintillation counters) are fully described in various releases and Catalog No. B7-54. A trailer-mounted air monitor for detection of radioactive fallout is available.—Nuclear Measurements Corp., 2460 North Arlington Ave., Indianapolis 18, Ind.

Asbestos-Cement Pipe Cutters—Two models of lightweight pipe cutters for asbestos-cement pipe are available.—Pilot Manufacturing Co., 3970 Pacific Coast Highway, Torrance, Calif.

Corrosion Resistant Coatings—Neoprene W, an economical single-package synthetic rubber coating, for use in corrosive atmospheres in general plant maintenance is described in Bulletin 701.—Carboline Co., 331 Thornton Ave., St. Louis 19, Mo.

Plant Instrumentation—Bulletin 90-242-11 shows the instrumentation possibilities for activated sludge and trickling filter treatment plants. Chlorinators, pH meters, O-R-P meters, controllers and recorders are discussed—Fischer & Porter Co., 554 Jacksonville Road, Hatboro, Pa.

Pilot-Plant Dryers—Ruggles-Coles rotary dryers for pilot plant or laboratory application are described in Bulletins AH-471, AH-472, and AH-473—Hardinge Company, Inc., York, Pa.

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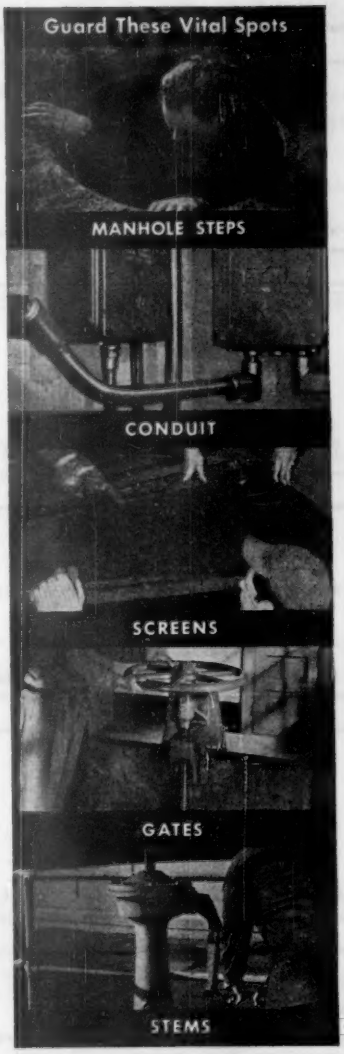

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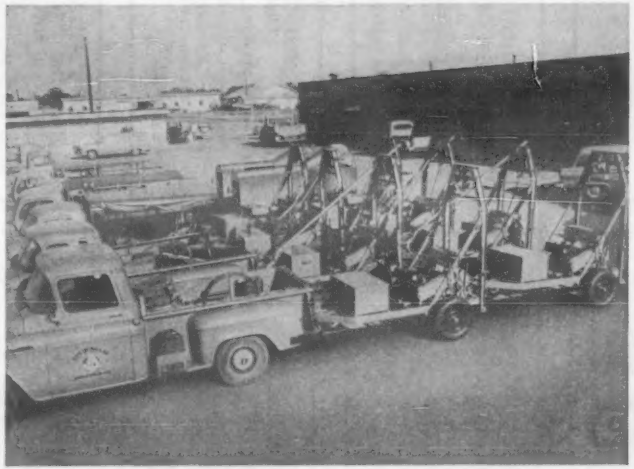

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